MECHANICAL ENGINEERING

INCLUDING THE ENGINEERING INDEX

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

World Leadership

The leadership of the ancient world rested mainly upon physical force. The trend of the more recent past through the present, toward the future, is for world leadership among the nations to rest mainly upon science and its applications. Already the progress of engineering is hampered and thwarted in many directions by lack of advance in the basic sciences. If only in the interests of applied science, the advancement of basic science in America should be stimulated and fostered. The national importance of this is so great that the need should be made widely known.

A. E. KENNELLY

(Retiring Chairman's Address to Section M, American Association for the Advancement of Science, Kansas City, December 30, 1925)

FEBRUARY 1926

THE MONTHLY JOURNAL PUBLISHED BY THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

Mechanical Engineering

The Monthly Journal Published by

The American Society of Mechanical Engineers

Publication Office, 207 Church Street, Easton, Pa. Editorial and Advertising Departments at the Headquarters of the Society, 29 West Thirty-ninth Street, New York

Volume 48 — February, 1926 — Number 2

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DEPARTMENTAL

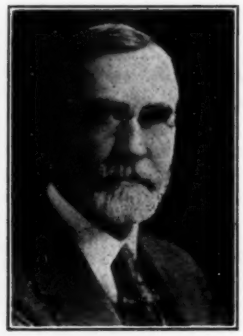
ADVERTISING

Price 60 Cents a Copy, $5.00 a year: to Members and Affiliates, 50 Cents a Copy, $4.00 a year. Postage to Canada, 75 Cents Additional; to Foreign Countries $1.50 Additional. Changes of address should be sent to the Society Headquarters.

Entered as second-class matter at the Post Office at Easton, Pa., under the Act of March 3, 1879.
Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized on January 17, 1921.

O. R. Wikander

D. L. Hoopingarner



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B. N. Broido

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Charles T. Main past-president of the A.S.M.E., was graduated from M.I.T. in 1876. He served for three years as an instructor in the Institute and then for several years was in mill work. He then formed an association with F. W. Dean and conducted business under the firm name of Dean & Main from 1893 to 1907, when it was dissolved. Since that time he has been in business as an engineer under his own name.

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At the Steam Table Research Session of the last Annual Meeting of the American Society of Mechanical Engineers there were presented eight reports. **Geo. A. Orrok,** who reported on general progress is chairman of the Steam Table Research Fund Executive Committee and is a consulting engineer of New York City. **R. V. Kleinschmidt** who presents the report on the Harvard experiments, is a Fellow for Research at Harvard University. **F. G. Keyes** and **L. B. Smith** who report on the progress of the work at the Massachusetts Institute of Technology, are connected with the Research Laboratory of physical chemistry at that institution. **N. S. Osborne** and **H. F. Stimson,** who together report on the progress of the work at the United States Bureau of Standards, are both associated with the Bureau, Dr. Osborne being physicist. **Harvey N. Davis,** who writes on the Joule-Thomson Effect, holds the chair of mechanical engineering at Harvard. **Robert C. H. Heck,** who writes on Comparison with the Formulations, is professor of mechanical engineering at Rutgers College. **J. H. Keenan** is engaged in development and research for the steam design of the General Electric Company's large steam turbines.

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MECHANICAL ENGINEERING

Volume 48 February, 1926 No. 2

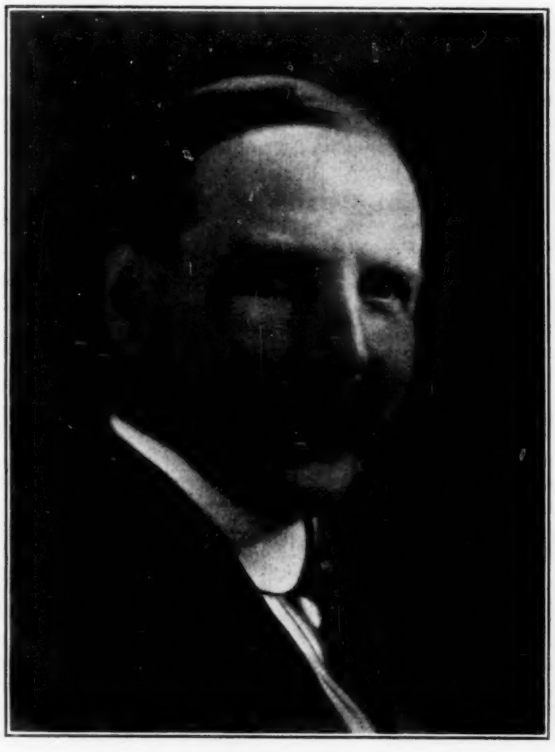
The Advancement of Engineering in Relation to the Advancement of Science

By A. E. Kennelly,[1] Cambridge, Mass.

The term "engineering" is employed with many different shades of meaning. Tredgold's famous definition of civil engineering, which appears in the charter of the Institution of Civil Engineers (London), dating from 1828, commences with the excellent phrase "—the art of directing the great sources of power in nature for the use and convenience of man." In Tredgold's time there were only two recognized types of engineering, i.e., civil and military. At the present time nearly forty different branches of engineering have been itemized in technical literature. For the purposes of this discussion the following broad definition is suggested to cover all types of non-military engineering: *the economic application of the sciences to construction, production, or useful accomplishment, especially on a large scale.*

From this point of view engineering manifests itself as the activating principle in the industrial world. Engineering in this sense must not only be coeval in antiquity with civilization, but the degree of engineering attainment in any age must also necessarily be an index or criterion of its civilization, judged from the material aspect.

If, as has been claimed by many writers, the acquisition and first permanent maintenance of fire marked the dawn of civilization in the early history of mankind, it would have been the province of the nascent engineering of that time to make a study of the laws of heat and combustion toward the maintenance and distribution of fire in tribal communities. To primitive man the science of combustion may well have seemed extremely difficult, elusive, and complex. The first rational notions on the subject were probably mingled with many errors and superstitions. These psychological stumbling blocks may have hampered and hindered, for many centuries, the attainment of the degree of thermal scientific knowledge appropriate to man's mental and moral development of that period.



A. E. Kennelly

Engineering in Early Times

Coming down to early historic times in ancient Egypt, we find a considerable increase in scientific knowledge and its application by engineering, confided to a priestly caste. The sciences were assiduously studied, and the knowledge thus acquired was jealously guarded by the esoteric. Considering how large, in the aggregate, are the literature, the statuary, and the painting of ancient Egypt that have been preserved to our own times, it is remarkable how few of their scientific records have been found. Taking into account their temples, pyramids, monoliths, canals, ships, and metal work, it is clear that their scientific knowledge was in highly developed application.

In ancient Rome the keynote of her empire was military power. She explored the sciences mainly for knowledge concerning armaments. Her great system of roads was primarily a system of military communication, for the most part constructed and maintained by the legions, often with the slave labor of conquered peoples. Engineering was mainly in the hands of military officers, who specialized in various branches of construction. Their scientific knowledge was mainly of a practical kind and their measuring instruments were relatively crude, but their engineering achievements were considerable, thanks to a national aptitude for practical accomplishment.

Through the Middle Ages and the Renaissance, art flourished; but engineering made little progress. Production remained in the hands of crafts and guilds. These developed great manual skill, but scarcely advanced the underlying sciences. Only in canals, shipbuilding, and masonry construction did notable advances occur. Engineering, recognized under that title, was practically confined to military works.

The present era, which is essentially an engineering age, may be said to date from the introduction of the steam engine, and in that sense is only about one hundred years old. The application of the science of heat, in relation to steam for generating power, rapidly changed the nature of production from the individual-worker system to the factory system, augmenting greatly the output of a day's work. This in turn brought new dense factory populations, and also brought the means of supporting them. The so-called industrial revolution thus started brought tremendous sociological changes in its wake. Rapid steam transportation accelerated commerce and developed markets. It enabled producers to find sales for their products over a continually enlarged area. A sense of economic emancipation dawned over mankind.

Scientific Work of Middle Ages Remote from Applications to Utility

During the Middle Ages and the Renaissance the study of science was slowly advancing in the Western World, mainly under the guidance of the universities. This study consecutively followed the growth of mathematics, and was seldom directed to engineer-

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Retiring Chairman's Address to Section M, American Association for the Advancement of Science, Kansas City Convention, December 30, 1925.

ing applications. The natural philosophers, chemists, and mathematicians who lived in the early years of the nineteenth century, taught and worked in intellectual regions usually remote from applications to utility. The rapid growth of the steam engine for driving factory machines, in the early years of the engineering era, brought into existence the mechanical engineer, who received his training in the workshop and factory. The mechanical engineer was compelled to study the nature of heat engines and of combustion, the laws of mechanics, and the properties of machines. This scientific study was, at first, more or less empirical and unsystematic. In the early days of mechanical engineering the physicists and scientists were ordinarily so far removed in their experiences from machines and engineering that they saw no way of coöperating with the engineer; while the engineer was so completely engrossed with the practical details of his work that he could see no way of receiving help from theoretical science.

The last few decades have steadily drawn together these two types of men and schools of thought, by mutual modification. The constantly increasing scale of machinery and machine production has necessitated more concentrated scientific study of the principles involved. The engineering applications have demanded more scientific knowledge, and the scientists have become more interested in applications. Until about fifty years ago the initial training of a young engineer after leaving school was either by apprenticeship to an engineering workshop, or by being articled, as an assistant, to a practicing engineer. It is now recognized that the best training is in an engineering school of a university or technical college, where special study is devoted to the fundamental arts and sciences, followed by technical or applied science in some particular branch.

Manufacture on a Large Scale Virtually Engineering Itself

It is not only in the particular fields of engineering that this close dependence of application upon the sciences has become essential, but also in manufacturing and general production. It may be safely asserted that manufacture on a large scale is so closely associated with engineering processes as virtually to become engineering itself. In other words, in order to carry on manufacture economically on a large scale the process is practically the same as engineering. There is the same need for scientific study of the principles and basic materials involved, the same need for careful and thorough design, with a view to eliminating waste in material, plant, or labor, the same need for experience and skill in the various stages of the work, and the same necessity for careful preliminary estimates of cost, as well as of checking the cost in successive stages.

Every labor-saving appliance in manufacture, and every scientific improvement introduced into its procedure, is a new evidence of the identity between modern manufacture and engineering. A manufacturing community, in modern times of competition and development, is of necessity an engineering community.

Prior to the amalgamation of science and industry in our present engineering age, the advancement of science was made mainly in places where science was studied and taught, i.e., in universities, or institutions of scientific learning associated therewith. Since the amalgamation, however, an increasing share in the advancement of science has been carried on in engineering establishments, i.e., in industrial laboratories, in factory laboratories, or in government and state laboratories. A large amount of scientific investigation is nowadays carried on in such institutions, either partly or wholly for economic and industrial advantage. It becomes the duty of scientific societies to collect, correlate, and preserve this scientific knowledge, which otherwise might become lost and forgotten. In future the advances of engineering, and of the sciences upon which engineering depends, will be so bound up and interconnected that whatever gives one a step forward must also give a like impulse to the other.

It would no longer be possible to maintain the huge populations of many large cities in the world without engineering, i.e., without the continued economic application of the sciences to the supply of the many products those cities require.

Although the needs of utility have in recent years either suggested or demanded numerous scientific researches, it is manifest that many other researches in the sciences are and will doubtless continue to be made exclusively for the truth's sake, and independently of any specific utilitarian need. It is only necessary to consider any scientific subject in all its bearings to realize that this must be so. The great science of mathematics, for example, must evidently be greater than the sum of all its applications; so that unless all scientific curiosity as to the nature of new mathematical relations shall disappear, many investigations must continue to be made into branches of the subject that appear to have no immediate applications. Moreover many cases of scientific research which have been made without any suspicion of applicability, have subsequently come to be applied to very practical use. It would seem that the only differences which necessarily separate a scientific research of the basic or non-applied type from one of the applied type, lie in the aims and motives of the researcher. In other words, one and the same research, conducted in the same way, may be an applied-science research or a basic-science research, according only to the purpose in the mind of the person who carries on the work.

It is generally conceded that researches carried on for the advancement of science tend strongly to stimulate the imagination. The investigator is called upon, at every stage of experimental inquiry, to speculate upon all the possibilities that present themselves, and to set up a new test that may serve to demonstrate which are the actualities and which the unrealities. It is not so generally recognized, however, that the work of the designing engineer also makes special claim upon his imaginative powers in the material realm. Any new project, such as a large bridge, building, railroad, or power plant, calls for a careful estimate and design. It has to be completely visualized, part by part, in the mind of the designer, before construction commences. The designer has then, either alone or with the aid of assistants, to realize his plans in two-dimensional drawings. A large project may involve the preparation of many hundreds of drawings in advance of assembling the materials. All of these drawings must interlock and connect in technique and dimensions. Tracings and blueprints from these drawings are then provided for guiding the constructors in their various tasks. The assemblage of design drawings embodies in most new undertakings a considerable amount of invention, imagination, and creative work, which the builders proceed to translate from small scales in two dimensions to full-size three-dimensional reality. To the trained eye a good construction blueprint reveals, under its network of lines, a wonderful image of reality.

In the engineering of building construction, provision is made for the proper conservation of esthetic grace by the profession of architecture. On its artistic side architecture seeks to foster and promote the art of beautiful building construction. This professional attitude toward art in the engineering of buildings guides public opinion in such a way that graceless and inharmonious buildings seldom escape popular censure. In other branches of engineering the esthetic quality of the product does not at present find a similar professional safeguard. Nevertheless there is for each type of engineering construction a certain somewhat indefinite standard of artistic appearance, below which the designers and builders are sure to encounter hostile criticism. In every country new types of machines which are experimental and have not yet established their right to survive, are usually revealed by their awkward appearance. Each country develops as a general rule its own type of esthetic standards in appearance, and experts frequently detect in this way the nationality of machines and the relative artistic engineering excellence of the nations in which those machines were produced. It is here again that the advancement of science reacts upon advancement in engineering; because the harmony in nature that scientific study discloses, tends to guide the minds of those who apply the great principles of nature to the satisfaction of human needs.

Advancement of Science Constantly Tending to Advancement of Engineering Processes

Just as the advancement of engineering construction, as, for instance, in telescopes, is constantly tending to the advancement of the sciences, or of astronomy in the case considered, so in return the advancement of science is constantly tending to the advancement of engineering process. Thus, the precision of geodetic

surveying has greatly increased during the last few decades, owing to progress in the sciences of astronomy, mathematics, physics, metallurgy, geology, and others. Moreover the demands made upon engineering design and construction tend ever to become more exacting. For example, it has recently been stated that the great new Philadelphia-Camden bridge across the Delaware River is the first in which the supporting towers have had to be given extra strength to withstand the possible accidental impact of an airplane.

So close is the present interconnection between science and engineering that the only salient distinction between them lies in their respective relations to economics. Questions of cost inevitably present themselves in the study of basic scientific problems, if only as limitations to equipment; but they are ever present in the study of engineering problems. Indeed, engineering problems call for special methods of accounting, and emphasize the importance of determining amortization, depreciation, effective rates of interest, and present values of plants. The stock takings of large-scale businesses likewise tend to become both economic and engineering inquiries.

Modern War, Engineering Gone Mad

As the entire civilized world becomes more and more given over to engineering, if only in order to support its large populations, it becomes evident that the conversion of factories for producing utilities into agencies for developing destructive and poverty-making warlike implements is ever easier. The power of science to create in the hands of those who help, becomes equally the power to destroy in the hands of those who fight. The world has only too recently seen how terribly destructive the powers of science and engineering can become among the industrialized nations. Modern war is engineering gone mad. This misuse is of course no fault of either science or engineering. If, however, in the reasonably probable advance of both we are to avoid the utter destruction of civilization by war, and the economic servitude of posterity in its wake, we must all unite in building an international organization that shall not only tend to prevent the onset of war but shall also swiftly suppress its first outbreaks. In any such organization both science and engineering are sure to be powerful elements for effecting control. Under such control, once successfully established, the advancement of science and engineering should surely promote and maintain world peace. Even now all science and its applications are essentially international. No way has been ever found to make science exclusively for the benefit of one nation, or one portion of the globe.

In the basic sciences the units of measure employed are almost universally the simple units of the international metric system—the meter and the gram—with their derivatives. In engineering and applied science the units employed have gradually likewise become metric in all parts of the world except in the English-speaking countries, where both the time-honored but cumbersome English and American systems of units persist. Even in the English-speaking countries, however, a gradual transition may be perceived toward the ultimately inevitable international metric system. When the transition shall have become complete, the mutual advances in engineering and in science will be rendered more easy and rapid through the use of the same language of units. This simplification will benefit science and engineering, not only in this country but also in all parts of the world where records in our units may extend.

The advances of science and of engineering have thus far always enriched mankind materially. Material production has been greatly hastened; so that the average possessions of men have been increased, or else larger populations have been supported to divide the increase. It is doubtful, however, whether increase of human happiness, beyond a relatively small modicum of possessions, is at all commensurate either with the growth of material wealth or with the growth of population. It seems that while science can largely increase general comfort and prosperity, it can, at present, insure but little increase of happiness and contentment. Whether this must always and inevitably be so, is debatable, and depends to some extent on our definitions of science. In any case we must turn for help to moral and spiritual sources of happiness if we are to continue to become increasingly indebted for material wealth to the scientific revelations of the interpretable universe. At present it appears that advancement in the power to enjoy and give contentment is more difficult for us collectively to acquire than advancement in the power to secure material benefit through science and engineering. In the discovery and maintenance of these uplifting philosophies the calm and contemplative Orient has surpassed the tense and restless Occident.

Tendency of Present Engineering Age Toward Accuracy of Reasoning and Precision of Thought

It is generally admitted that the study either of the sciences or their applications tends to produce in the mind of the student a sense of humility and a respect for truth. Indeed, it is not strange that habits of seeking or applying scientific truths should engender habits of faithful thinking. In this respect there is encouragement in the belief that the tendency of the present engineering age is, on the whole, toward accuracy of reasoning and precision of thought. Scientific ideas may tend slowly to dominate over irrational and irregular thinking. A casual review of general literature over long periods of time seems to show that as science has advanced, irrational and superstitious ideas have dwindled. The concomitant danger, however, lies in the occasional ravages of erroneous pseudo-scientific doctrines. A plausible but false doctrine that masquerades as a scientific proposition may produce more harm in a scientifically disposed world than a flagrantly immoral popular belief of a clearly irrational character. The responsibility for making unguarded statements that are unsupported scientifically thus rests increasingly upon all speakers and writers.

In the development of the applied sciences a constantly increasing demand devolves upon the underlying basic sciences. In the prehistoric times of primitive engineering only the simple rudiments of the underlying sciences may have been involved. In the ancient Egyptian and Roman days engineering must have demanded a closer study of mathematics and physics for support. Since the dawn of the present engineering age, however, much more knowledge and research have been demanded in a long list of the branches of basic science. Invention is always needed. But whereas in past times inventors, if they had the requisite talents, did not need much scientific knowledge, at the present time the successful inventor has not only to be endowed with inventive ability but he must also be well versed in basic science. It appears that in the future this demand for basic scientific knowledge as a prerequisite to applied-science progress will continually increase.

Tendency for World Leadership to Rest Mainly upon Science and Its Applications

The leadership of the ancient world rested mainly upon physical force. The trend of the more recent past through the present, toward the future, is for world leadership among the nations to rest mainly upon science and its applications. Already the progress of engineering is hampered and thwarted in many directions by lack of advance in the basic sciences. It is to these that national attention should be directed for the progress of the knowledge that benefits first the nation in which it is made, and later all the other nations. If only in the interests of applied science, the advancement of basic science in America should be stimulated and fostered. Support for applied science is likely to be forthcoming from the industries themselves; but support for basic science is more difficult to secure. The national importance of this is so great that the need should be made widely known. An effective way to stimulate advance in the sciences in this country would be to secure permanent endowment for a suitable annual prize to the most notable contribution each year in each section of the American Association for the Advancement of Science. This official recognition of scientific achievement would stimulate and encourage researchers in all the sections. There is no reason to fear that such scientific progress might be practically valueless. Useless scientific knowledge is now a contradiction in terms. Moreover, aside from the question of immediate versus future applications, the patient, earnest study of truth in those parts of the universe that are attainable to us mortals constitutes the noblest quest with which we are yet acquainted.

FIG. 1 ARCHITECT'S DRAWING OF FRONTAGE OF MUSEUM BUILDING ON EXHIBITION ROAD—NOW UNDER CONSTRUCTION

The Science Museum, South Kensington, London

BY H. W. DICKINSON,[1] LONDON, ENGLAND

THE Science Museum in London, England, is a typically British institution inasmuch as it can look back over a long and checkered career—nearly three-score years and ten—impinged upon and molded by thought and action from without, yet maintaining within itself a core and purpose that has served to keep it young, so that we find it today better organized and better equipped than it has ever been before. It will be time not ill spent for interested people in America who contemplate following the example of Great Britain and other nations, to consider awhile the rise and progress of the Science Museum.

For its origin we must go back to the Great Exhibition of All Nations held in the Crystal Palace in Hyde Park in 1851. At that time England might be said to have been in the heyday of her industrial development. It had been extremely rapid, however, and it was generally realized, and by no one better than H.R.H. the Prince Consort, that there was great need of instruction and improvement in the industries of the country. Hence the establishment of the Science and Art Department of the Committee of Council on Education. From its inception in 1853, a museum was contemplated as an integral part of the activities of the Department.

THE EMERGENCE OF NEW IDEAS

A museum, strictly speaking, is a temple of the Muses—the goddesses of poetry, music, and the liberal arts—and in early times the term was confined to such edifices. Later, however, it began to connote a collection of curiosities, practically always relating to archaeology or natural history. In the middle of the 19th century the collection of objects with a definite educational aim was a new conception. In 1857 the Museum of Science and Art, the nucleus of which was a collection of objects retained from the Exhibition mentioned above, was opened to the public in temporary buildings on the Kensington Gore estate, South Kensington. It was known by the latter name, and as such is still familiarly referred to. The work was taken up with great enthusiasm by Sir Henry Cole, K.C.B. (b. 1808 d. 1882) one of the great public servants of whom Britain has produced so many. While the Art Collections were developed rapidly and with great good judgment, in comparison the Science Collection received little attention. The latter comprised at first (*a*) Foods and Animal Products and (*b*) Teaching Apparatus, a subject that had at that time received scarcely any attention. The last-named collection had been formed in 1854 by the Royal Society of Arts and was presented by that body to the Government. Building Materials and Structures were added later, under the charge of officers of the Royal Engineers who were employed on the new museum buildings that now began to spring up.

FRESH INFLUENCES ON THE MUSEUM

Independently of these activities, but destined to have an important influence upon them, another institution was growing up. This was the Patent Office Museum formed by the energy of Bennet Woodcroft, F.R.S., Clerk to the Commissioners of Patents, at that time a branch of the judicature directly under the Master of the Rolls and responsible to the Lord Chancellor. Unlike the museum of similar name in Washington, D. C., the scope of this institution was sufficiently wide to include any machine, etc., that embodied invention; moreover there was no obligation upon a patentee to contribute. This museum was opened also in 1857 on a site adjoining the Museum of Science and Art.

Although a large revenue accrued then as today to the Exchequer from the fees on granting of patents, Mr. Woodcroft was unprovided with funds for purchases; his personal influence was such, however, that he surmounted obstacles that would have daunted a smaller man, with the result that he preserved for succeeding generations objects of very high technical importance—we may instance the locomotives "Puffing Billy" and "Rocket," Arkwright's cotton machines and Bell's "Comet" engine—that would otherwise have been scrapped. Such things were at that time as they are we fear in the States today, like silver in the days of Solomon, "not anything accounted of."

After the retirement of Mr. Woodcroft in 1876, the Patent Museum languished, and on the recommendation of a Committee, authority was given under the Patent Law Amendment Act, 1883, to hand over to the Science and Art Department such of these objects as were suitable. With these and an existing small collection, the Machinery and Inventions Division of the Museum was constituted.

But we are anticipating, for before this happened the Museum had been deeply influenced by the foundation, in 1864 at South Kensington, in charge of the Department, of the Royal School of Naval Architecture under the aegis of the Admiralty. As an adjunct to it a Naval Models Collection was formed, largely consisting of objects from Somerset House, then the office of the Admiralty, where they had accumulated for over half a century. The Admiralty models did not remain long, for the school was reorganized in 1873 and the objects were transferred to the Royal

[1] Honorary Secretary, The Newcomen Society for the Study of the History of Engineering and Technology.

Naval Museum at Greenwich. The interval had been long enough, however, for vigorous development by gifts and loans from private individuals, shipbuilders, and shipping companies. This has gone on subsequently, and the collection is now perhaps more representative and of greater extent than any other of its kind elsewhere.

A further great stimulus was afforded to the Museum in 1876 when a loan collection of scientific apparatus was brought together by the Department. This illustrated the applications of physics, chemistry, astronomy, and other sciences, and was happily international in scope. The residue left at the close of the Exhibition formed a nucleus that has been steadily enlarged in coöperation with the teaching staff of the Royal College of Science (subsequently the Imperial College of Science and Technology), another branch of the Science and Art Department.

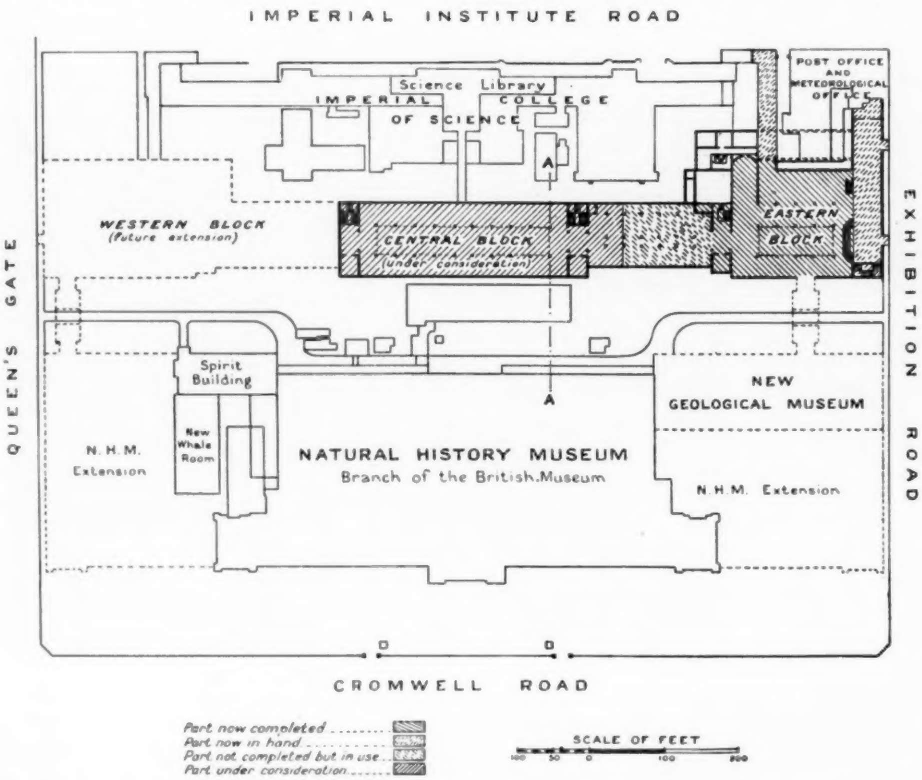

FIG. 2 PLAN OF NEW SCIENCE MUSEUM AND SURROUNDINGS, SOUTH KENSINGTON, LONDON, ENGLAND

REORGANIZATION

In 1889 the direction of education in England and Wales was taken over by the Board of Education and constituted a Department of State for that purpose, and the South Kensington Museum went over with the Science and Art Department. In 1908 the Science Collections were separated from those of Art and began an independent existence under the title at the head of this article.

BUILDINGS AT SOUTH KENSINGTON

It has been mentioned above that soon after an establishment of the South Kensington Museum, permanent buildings began to be erected. It was the original intention that all the Collections, both Science and Art, should be housed together, but as time went on growth was so sustained that it began to be realized that the site was inadequate for the purpose. Exhibition space for the Science Collections was obtained in the galleries erected for the International Exhibition of 1862, separated from the original site by Exhibition Road.

It would take too much space to summarize even an account of the recommendations of Commission and Committee, one after another, as to what ought to be done. It is sufficient to say that the Government sanctioned the erection of the striking pile of buildings that we see today, known as the Victoria and Albert Museum.

All this time science remained, like Cinderella, in obscurity. The collections, which were already of great value, were hidden away in temporary buildings, the entrance to them being of corrugated iron, and irreverently referred to as the "shooting gallery." Matters were not allowed to remain in this unsatisfactory state, however, for a deputation of prominent men in all branches of science, led by Sir Henry Roscoe, M.P., F.R.S., urged upon the then president of the Board the claims of science.

One cannot help wondering whether in time to come people will not look back and be surprised to learn how cavalierly science—the very life blood of the nation's industries—was treated, while art, which after all is ancillary thereto, was housed palatially. It only reflected the opinion of those immediately concerned, however, and to prove this we need only instance the Art Gallery given to Birmingham by Sir Richard Tangye with money made out of engineering in an industrial city, or the Royal College of Music given to the nation by Samson Fox, whose fortune was derived from the manufacture of steel. One would conclude that it was almost indecent to engage in industry, but having done so, and been successful, only a peace offering to the Muses would suffice as reparation.

DAWN OF A NEW ERA FOR THE SCIENCE MUSEUM

After long years in the wilderness, the Promised Land now seemed to be within sight. A Departmental Committee was appointed in 1910. Their final report presented two years later was eminently authoritative and far-seeing. In general not only the continuance of existing collections and their enlargement on definite lines was recommended, but new functions were adumbrated. Envisaging the requirements over an extended period the Committee laid down a comprehensive scheme, but, knowing British psychology, recommended that a beginning with only about one-third of it be made, comprising accommodation of 135,000 square feet of floor space on the existing site—a narrow strip of land fronting on Exhibition Road and Queen's Gate and sandwiched between the Natural History Museum and the Imperial College of Science and Technology. (See plan and section, Figs. 2 and 3.) Toward the cost of the scheme the Royal Commissioners of the 1851 Exhibition promised £100,000.

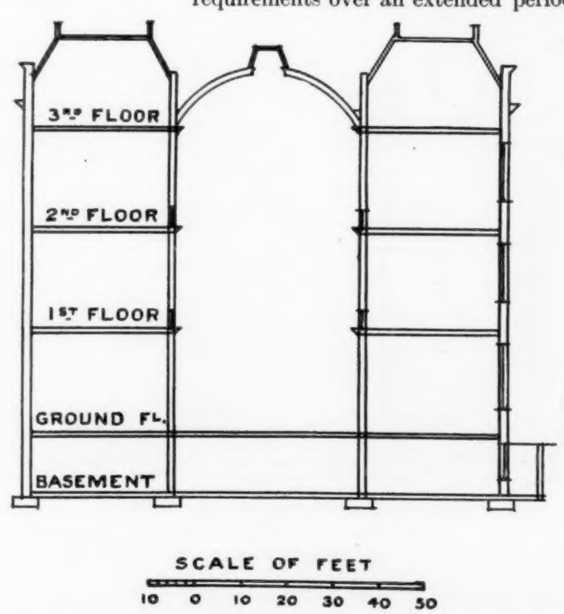

FIG. 3 SECTION THROUGH A-A OF PLAN OF THE SCIENCE MUSEUM, SOUTH KENSINGTON, SHOWN IN FIG. 2

The Government sanctioned this part of the scheme and work was at once begun. The reinforced-concrete shell was about half completed when the Great War broke out, and little by little progress was arrested and finally was stopped. The need for Government-office accommodation became very insistent in 1917–1918, hence the shell was hastily made habitable by temporary expedients and handed over to departments requiring it. Thus once more was hope deferred.

What with financial economies and the Geddes Committee, alternative accommodation could not be provided till 1922, and even then work was resumed on only a portion of the building. Contractors' delays resulted, and the ground floor of this portion was not handed over in the finished state till December, 1924. The appearance of rooms on this floor is shown by Figs. 4 and 5. The remaining floors are now (December, 1925) being occupied (see Figs. 6 and 7). Work on another portion of the building—the frontage to Exhibition Road (Fig. 1), which has been an eyesore for nearly a decade—has now been started.

These buildings are admirably planned, dignified in their simplicity, and well lighted, with ample provision for electricity, gas, water, and compressed-air services on all floors. Part and parcel of the scheme is a conference hall for holding the gatherings of scientific societies, for congresses, and for lectures, while demonstration rooms each holding about 100 people are provided on every floor for the use of smaller gatherings such as school teachers bringing classes. The latter is a privilege greatly appreciated.

Owing to the fact that buildings had to be pulled down to enable the scheme of 1912 to be started at all, the existing congestion was increased, and this was made worse by the ordinary additions that were continually going on. Early in 1924 detached galleries of approximately 30,000 square feet area had to be given up to make room for the Imperial War Museum, and at this time the contents of the Museum may be said to have been warehoused rather than exhibited, since quite 25 per cent of its objects were in store.

Fig. 4 East Hall, Ground Floor of the Science Museum, South Kensington—Stationary Engines
(The large engine at the left is an atmospheric engine, dated 1791.)

Scope of the Museum

The Museum embraces broadly the applications of physical science, excluding natural history, geology, and medicine; these are provided for by other institutions, overlapping with which is avoided. It is not attempted to cover every application of physical science—indeed, there is obviously no finality in the matter. This leads to the observation that it is unwise to delimit the scope of such a museum: it must be considered as an organism capable of growth as knowledge broadens.

At present the Museum comprises the following groups:

Stationary engines and boilers
Land transport; roads; railways
Lifting appliances
Power transmission
Pumps; fire protection
Structures and building construction
Water supply; sewage; sanitation
Textile machinery; sewing machines
Agricultural implements and farm machinery

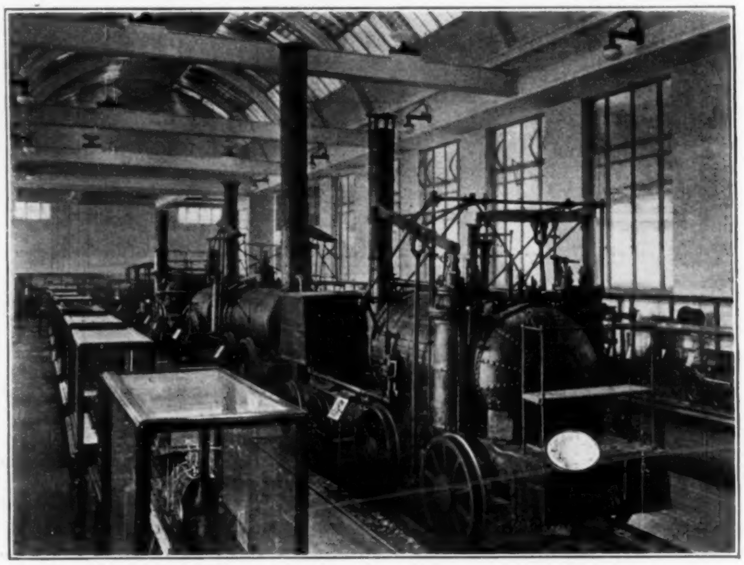

Fig. 5 Room 3, Ground Floor, the Science Museum, South Kensington—Locomotives
("Puffing Billy" is shown in the foreground.)

Mining, ore dressing, and metallurgy
Paper making; printing; writing; copying
Electrical engineering
Telegraphy; telephony, wireless
Lighting appliances
Machine tools
Marine engines
Ship models; naval architecture
Harbors and docks; lighthouses
Aeronautics; aero engines
Horology
Astronomy
Geography; geophysics; oceanography
Optical instruments
Photography; kinematography
Mathematics
Meteorology
Thermal instruments
Properties of matter; physical phenomena
Acoustical instruments
Geodesy; surveying; cartography
Chemistry
Biology.

In conjunction with these groups there is a Library—but it is something more than this, for it is especially rich in the transactions of learned societies and in scientific journals published in all quarters of the globe. There is a set of the British Patent Specifications, but overlapping with the public library attached to the Patent Office is avoided.

The human element is not forgotten, for portraits of discoverers, inventors, and scientific men are displayed.

Aim and Purpose

Speaking broadly, the aim of the Museum is to illustrate in three dimensions development from the earliest times to the present day in each of the groups named, and to present the illustrations in chronological order as far as practicable. A scheme has to be

thought out beforehand requiring knowledge and research. The desiderata have then to be got together, and as actual objects of past days are difficult to come by, they must be reproduced. Objects illustrating modern developments and current practice are obtained more readily. The courtesy of private individuals and manufacturing firms can generally be relied upon for these objects. Usually they are obtained on loan, for it is too much to expect gifts, and financial considerations preclude purchase.

Fig. 6 Room 22, First Floor, the Science Museum, South Kensington—Mining
(In the foreground is a model of a coal-washing plant.)

Objects in time may pass from this into the historical category, but, generally speaking, the modern material must be subjected to periodical revision to make way for more recent objects, although the historical part will be permanent. Such revision is vital, else the "wood cannot be seen for the trees." The practice of obtaining modern objects on loan tends to the desired fluidity.

Very rarely is an object self-explanatory, and recourse is had to sectioning, or, if involving mechanism, to arranging it so that it can be put in motion. The means for doing this have been alluded to, and it need only be said that this great step in museum technique is due to a late Director, William I. Last, Wh.Sc. Such aids are backed up by printed descriptions and diagrams. In this way historical data as well as information regarding construction and working are conveyed to the visitor.

In all these ways the divergence of a science museum in constitution and operation from, say, one devoted to art or archaeology, will be realized to be fundamental.

The compilation of catalogs embodying the museum labels with historical notes has always received attention, and the practice now is to issue them sectionally to cover a group or part of a group at a price somewhere about one shilling per copy. Editions are not large enough to enable them to be sold for less, as would be desirable.

The following catalogs have been issued or are in immediate prospect:

Mining and ore dressing
Miners' lamps (in press)
Metallurgy
Machine tools
Stationary engines and boilers

Land transport:
- i Roads and animal vehicles
- ii Mechanical road vehicles
- iii Locomotives and rolling stock
- iv Railway Centenary, 1925

Water transport:
- i Sailing ships
- ii Steam ships of war
- iii Merchant steamers (in press)
- iv Marine engines and boilers (in press)

Textile machinery
Aeronautics
Aeronautics supplement
Electrical communications
- i Wireless telegraphy and telephony

Geodesy and surveying
Meteorology
Biology
Mathematics
- i Calculating instruments (in press)

A number of other catalogs are in preparation.

Guide-Lecturer

Even such aids to the visitor as are described above had been felt to be inadequate and the services of a guide or lecturer had been in prospect for several years, but it was not till 1924, when the congestion of exhibited objects was lessened by the completion of a portion of the new building, that lecturing became practicable and an appointment was made. The lectures are given twice daily, except Sundays, at convenient hours. The attendance so far has justified the innovation. The prospect opened out is extensive, and much more may be done in the future in this direction, as experience dictates.

Administration

The Science Museum is administered by the Board of Education and is supported from appropriations under that department. There is no revenue from trust or other funds. There is an honorary Advisory Council of distinguished men

Fig. 7 Room 23, First Floor, the Science Museum, South Kensington—Metallurgy
(The model in the foreground is that of a blast-furnace plant.)

who advise the President of the Board as to the needs and program of the Museum and report annually.

The directing and technical staff of the Museum comprises 1 director at £1200; 3 keepers at £750–900; 2 deputy keepers at £600–750; 12 assistant keepers and assistants at £400–600 and £250–400, respectively; 1 guide-lecturer at £320; and 8 technical assistants at £150–250. This, however, is not a permanent establishment. A cost-of-living bonus is paid in addition to the above salaries. The Director is appointed by the President of the Board of Education; the rest of the staff is obtained by a selection board.

For administration purposes the Museum is divided into four divisions—the Library ranks with them—and each is in charge of a keeper or deputy keeper.

There is a staff of attendants, artisans, laborers, and warders for the thousand-and-one jobs required in the making of objects; renovating, repairing, and adapting for exhibition; cabinet making

joinery, and polishing, keeping the objects and the buildings clean, and guarding the contents day and night.

The estimated cost of the Museum during the financial year 1925–1926 is as follows:

Salaries and wages	£45,440
Apparatus, materials, etc., for mounting, repair, and fitting up of objects	3,250
Traveling, freight, printing catalogs and postcards	2,000
Telegrams and telephones	250
Purchase grant	2,000
Total	£52,940

The cost of additions to the collections and to the Library is met from this purchase grant, which, unlike the sums under the other items mentioned, is not returnable to the Treasury if unexpended. Accumulation is thus possible to meet abnormal expenditure in a single year.

The costs of maintenance of buildings, fuel, lighting, furniture, stationery supplies, and superannuation are charged on the votes of other government departments, and the amounts of these are not available.

The Museum is open to the public daily, free (except Christmas Day and Good Friday), from 10 a.m. to 6 p.m. weekdays, and 2.30 p.m. to 6 p.m. Sundays. The Library remains open till 8 p.m. on Thursdays and Saturdays. Admission to this is by ticket.

General Observations

This is not the place nor is it the time to offer any suggestions as to the aim or scope of a Museum of Science for America such as the one that is, I understand, proposed for Engineering and Industry. The scheme will have to be worked out—with success, I hope, but perchance not without failures—by those on the spot. A few general observations may, however, be permitted.

First, let us take to heart the pregnant words of Francis Bacon, Viscount St. Albans, in *Nova Atlantis*, 1617, when describing Solomon's House, the temple of knowledge in his ideal state. His words have been many times quoted but will bear repeating:

> *For our* Ordinances *and* Rites: *Wee haue two very* Long, *and* Faire Galleries: *In one of these wee place* Patternes *and* Samples *of all manner of the more* Rare *and* Excellent Inuentions: *In the other wee place the* Statua's *of all* Principall Inuentours. *There wee haue the* Statua *of your* Columbus, *that discouered the* West-Indies: *Also the* Inuentour *of* Shipps: *Your* Monke *that was the* Inuentour *of* Ordnance, *and of* Gunpowder: *The* Inuentour *of* Musicke: *The* Inuentour *of* Letters: *The* Inuentour *of* Printing: *The* Inuentour *of* Obseruations *of* Astronomy: *The* Inuentour *of* Works *in* Mettall: *The* Inuentour *of* Glasse: *The* Inuentour *of* Silke *of the* Worme: *The* Inuentour *of* Wine: *The* Inuentour *of* Corne *and* Bread: *The* Inuentour *of* Sugars:

We shall all agree that the great men of invention, industry, and science, by whose labors the peaceful arts of the world have been built up, should receive, if only tardily, the meed of recognition. It may be that we shall realize that these men are, albeit unconsciously, the motive power behind the kings, statesmen, and generals who have hitherto monopolized the stage of history.

Parenthetically it may be remarked that America has every reason to be proud of the long roll of men of invention to whom she has given birth, to mention only Whitney, Fulton, Morse, Howe, McCormick, Westinghouse, and Edison. The footprints of such men in the sands of time must be shown to the generations coming on.

From a cultural point of view, a Museum of Science, properly organized, offers even to the non-technical person many advantages over other kinds of museums, since its underlying idea—that of development—runs like a warp through the loom of all activities of civilized man. The idea is one that is easily grasped, and he realizes that he is facing not the dead past but something living, something part of himself, something that touches his "business and bosom."

Again, in the world today where but for the work of the engineer and scientist millions could not continue to exist and where political power is in the hands of the million, it is the merest common sense to bring to the people the wisdom and understanding that will fit them to become good citizens. In achieving this task a Museum of Science can fill no mean role.

This leads to the reflection that such an institution could be made a center whence information as to scientific work that is being done in State Departments at public expense could be radiated by lecture or otherwise to the public. Such information is available, it is true, but in far too technical a dress. Something of this nature has been going on in the Government Pavilion at the British Empire Exhibition at Wembley, and has met with much acceptance.

To conclude, it behooves all engineers and scientific men, if they see anything in what has been said, to state that they want such a Museum, that they are determined to have it, and will put their shoulders to the wheel to get the money. The general public will be delighted when they see it an accomplished fact, but can not envisage it enough to demand it.

Technical Training in Woodworking

Summary of Replies to a Questionnaire Sent to 750 Public Schools, Colleges, and Universities by the Wood Industries Division of the A.S.M.E.

By THOMAS D. PERRY,[1] BOSTON, MASS.

The Wood Industries Division of The American Society of Mechanical Engineers, in studying the problem of closer coöperation between woodworkers and engineers, have felt that the existing educational facilities may underlie the present lack of coördination between the broadening field of industrial engineering and the imperative need of utilization and conservation measures in the wood-consuming factories.

Woodwork has always been regarded as a relatively simple trade, requiring little experience and a minimum of capital. It is actually among the half-dozen largest industries in this country, and under existing conditions from 50 per cent to 75 per cent of the tree goes to waste. Not only is the waste inexcusable but a shortage of merchantable hard and soft wood timber is impending, and costs of lumber are sure to increase. The situation is a challenge to the engineer to use Nature's wealth of trees in a more effectual manner.

The familiarity of the small boy with filling the wood box, not to mention other wood-shed experiences, and the ubiquity of the hammer, saw, and chisel have dispelled any semblance of mystery, or any curiosity that prompts investigation. Undoubtedly nearly all boys have their first contact with wood not only in the home as suggested above, but also in the public school. It may be worth while to inquire what impression is made by these first contacts.

The Questionnaire

A questionnaire was sent out to some two hundred and fifty cities (of populations over 30,000 by 1924 estimate) with regard to the woodworking branches taught in their public schools, and to some five hundred colleges, universities, and institutes, asking what courses, if any, were offered in any branch of woodworking subjects.

The opening paragraphs in the questionnaire letter—

> Education or training in woodworking, or courses in wood utilization, do not appear to be usual in American schools, colleges, and universities; in spite of the fact that woodworking in its many branches affords one of the finest fields in which to train and develop manual dexterity, design, and proportion, as well as artistic effects.

[1] Secretary, Bigelow, Kent, Willard & Co., Consulting Engineers and Accountants. Mem. A.S.M.E.

Apparently the simplicity of and familiarity with the woodworking trades seem to have discouraged school training, leaving the manufacturers (neither pedagogically nor financially equipped to do so) under the necessity of training their own workers. The result has been an increasing scarcity of skilled artisans in a major branch of industry that supplies our cribs and coffins, our homes and furniture, our transportation by land, sea, and air, our office furnishings, and our sport equipment.

brought forth the following rather sharp comments from Philadelphia, Ohio, and Illinois:

They are usual in schools. Woodwork is emphasized more in public schools than other mechanical activities.

The first statement is not true in elementary and secondary schools of America, and the second premise also is not true.

The first statement is wrong.

Replies Received to Questionnaire

Replies were received from nearly fifty per cent of the institutions to which questionnaires sent, and these fall into three rather clear educational classifications:

- Public schools in the grammar and high-school grades
- Public and private vocational and trade schools, including public evening and continuation courses
- Public and private colleges, universities, and technical institutes of college grade.

Craftsmanship Training

The vocational and trade training is more difficult to isolate and is essentially to develop workmen and artisans, and therefore less interesting for the purpose of this investigation than the fundamental public-school grades, and the advanced education for woodworking executives and engineers.

It is obvious that elementary woodwork training in the public schools must serve as the foundation to subsequent courses either in craftsmanship, the function of trade and vocational instruction, or in woodwork engineering, the function of the higher technical institutions.

Some of the replies received do not discriminate as clearly as might be between trade training and instruction in the technical management of woodworking industries, due probably to combining both subjects in a single questionnaire.

It has been the purpose of this questionnaire, however, to explore the availability of collegiate courses of instruction directed toward the management and administration of woodworking industries with the avowed purpose of developing scientific solutions of the many unsolved problems of woodwork and woodworkers.

TABLE 1 PUPILS ATTENDING WOODWORKING COURSES IN PUBLIC SCHOOLS IN CITIES

State	Principal cities Asked	Principal cities Ans'd	Population of cities answering	Pupils in Woodworking Studies: Elementary Hand work	Car-pentry	House const.	Cabinet and furni-ture	Pattern making	Other courses
Alabama	3	3	297,114	1,500	1,500	100	850		
California	11	4	1,239,652	23,075	..	26	2,770	30	..
Connecicut	7	6	528,186	2,600	4,753	69	104	..	71
Dist. Columbia	1	1	437,571	..	..	...	6762	350	..
Florida	4	2	131,949	300	315	...	89	..	700
Georgia	5	1	55,378	N.S.	N.S.				
Illinois	14	4	183,217	2,050	..	...	717	150	..
Indiana	10	4	538,394	750	38	14	366	76	160
Iowa	6	4	211,644	600	12	...	385	6	81
Kansas	3	1	113,801	..	300	...	1,250	..	..
Kentucky	3	1	236,612	2,011	..	...	460	2,743	..
Louisiana	2	1	399,616	N.S.	N.S.				
Maine	2	1	72,027	550	..	...	..	..	..
Massachusetts	26	13	1,804,689	9,490	6,150	...	2,502	519	1,158
Michigan	13	2	200,442	400	25	...	50	20	..
Minnesota	3	2	344,019	15	15	...	1,062	247	..
Missouri	4	3	457,451	600	6	6	30	..	..
Nebraksa	2	1	57,308	88	..	...	430	..	..
New Jersey	17	8	798,585	11,279	953	...	1,669	172	2,595
New York	20	5	829,137	3,040	150	48	348	72	80
North Carolina	3	3	136,008	..	..	16	165	..	..
Ohio	16	6	1,688,849	15,400	3,310	40	2,435	1,140	3,800
Oklahoma	3	2	186,960	1,200	12	...	1,039	18	..
Oregon	1	1	268,875	4,200	..	...	320	..	..
Pennsylvania	20	11	3,110,071	17,937	22,021	97	4,273	830	645
Rhode Island	4	3	353,048	308	130	26	490	..	..
South Carolina	2	1	70,305	N.S.	N.S.				
Tennessee	4	2	227,215	750	1,500	300	400	322	..
Texas	10	5	361,903	1,600	40	...	1,375	10	..
Virginia	7	1	178,588	3,000	..	...	..	..	..
Washington	3	1	104,570	N.S.	N.S.				
West Virginia	3	2	98,275	1,500	..	...	950	40	300
Wisconsin	9	2	73,112	..	48	48	375	75	420
Other states (16)	13	...							
Totals	254	107	15,785,571	104,243	41,278	790	31,652	6,820	10,010

Per cent replies........ 42½ per cent
Total U. S. population....... 112,078,611
Per cent of total population covered by table.... 14 per cent

TABLE 2 STUDENTS TAKING WOODWORKING COURSES IN INSTITUTIONS OF COLLEGIATE RANK

I—Technical Institutes

Name	Cabinet work	Pattern work	Fur-niture const.	House and farm machy.
Bradley Polytechnic Institute, Peoria, Ill	25	30	25	
California Inst. Technology, Pasadena	160	160		
Carnegie Inst. Technology, Pittsburgh, Pa	20	20	10	80
Case School Applied Science, Cleveland, Ohio		90		
Cornell University, Ithaca, N. Y		320		
Lafayette College, Easton, Pa		110		
Lewis Institute, Chicago, Ill		12	28	8
Mass. Inst. Technology, Boston, Mass		100		
Polytechnic Institute, Brooklyn, N. Y	130	130		
Purdue University, Lafayette, Ind	N.S.	N.S.		
Rice Institute, Houston, Texas		30		
Rose Polytechnic Institute, Terre Haute, Ind		130		
Southwestern Louisiana Inst., Lafayette, La	30	30	30	
Villa Nova College, Villa Nova, Pa	170	35		
	535	1197	93	88

II—State Universities

State	Name	Cabinet work	Pattern work	Furniture const.	House and farm machy.
California	University of California		90		
Delaware	University of Delaware		40		
Illinois	University of Illinois		230		
Michigan	College of Mines		50		
Minnesota	University of Minnesota		380		
Missouri	University of Missouri		170	170	
Nebraska	University of Nebraska		60		
Nevada	University of Nevada		10		
New Mexico	University of New Mexico	40	40		
New York	Syracuse University		60		
North Dakota	University of North Dakota		70		
Ohio	University of Ohio	17	157	17	
Oregon	Oregon Agricultural College	30	75	30	
Rhode Island	Rhode Island State College		85		
South Dakota	University of South Dakota		Few		
Vermont	University of Vermont	40	40		
Virginia	University of Virginia	50	50		
Washington	Washington State College	52	2	40	22
Wyoming	University of Wyoming	20	20		10
		249	1629	257	32

III—Other Colleges

Name	Cabinet work	Pattern work	Furniture const.	House and farm machy.
Bucknell University, Lewisburg, Pa		80		
McPherson College, McPherson, Kansas			16	
Miami University, Oxford, Ohio	50			12
Nebraska Wesleyan University, Lincoln, Neb	16	5		7
Northwestern University, Evanston, Ill		30		
Ohio University, Athens, Ohio	40	20	10	
Washington University, St. Louis, Mo		50		
	106	185	26	19
Grand total	890	3011	376	139

City Public Schools

The replies received from over one hundred cities are summarized in Table 1, and undoubtedly show an average cross-section of the extent to which instruction in woodwork is used for manual-training purposes. Only city schools were canvassed, and it is possible that rural schools might show a somewhat greater emphasis placed on woodwork. The results of this investigation would seem to show that woodwork is generally recognized as a basis for instruction in the manual arts, but the comments made in reply to direct questions leave grave doubts as to whether the boy completes his school shopwork with any enthusiasm or further interest in woodwork, or the least ambition to follow the subject of wood utilization as a career.

These comments as to why a woodworking career is not more emphasized are, for the most part, made by directors of manual training, who may be either normal-school-trained without much actual woodwork contact, or practical shop-trained without broad contacts in the educational field.

Many statements similar to the following are made:

All high-school courses are set up for college preparatory standards, and no credit is allowed for woodshop work.

Educators are, for the most part, academically trained and do not appreciate the value of woodwork instruction. Few educational administrators are scientifically or shop trained.

Woodworking is an old subject, and we all run to new fads.

More can be expressed in woodwork, in the way of design, than in metal, but metal work is more popular and better equipped.

We appeal to the boys with the beauty of the wood, and the satisfaction of making articles of home and individual utility.

Woodwork is not interesting to boys, partly because the method of teaching is faulty, partly because woodworkers' pay is low, and somewhat because pupils feel that manual training is not education.

Woodwork must be "sold" to pupils as well as any other subject.

Greatest emphasis has been placed on woodworking, but automobile and radio are diverting students.

All educational thought seems to want to relieve the pupils of all responsibility and cater to their whims.

Only a limited demand for trained woodworkers.

Woodworking most popular mechanical department; lack of time prevents more pupils from taking it. Boys always choose woodwork first.

Woodworking training is not fundamental.

The school inertia of one thousand years, with its effect on parents and teachers alike, is the reason that industrial work gets so much less emphasis than academic studies.

We have too much of "Mama wants little Willie to take Latin, so he can go to college," and the sole aim of going to high school or college is to get out of having to do a job that requires work.

Only half of city boys even carry a pocket knife, and know nothing about wood.

Majority of school executives of older type see little value in vocational work as they know so little about it. Others use vocational courses as a dumping ground for inferior pupils. High-school rating secured according to academic standards.

Several cities, among them Los Angeles, Madison, Cleveland, and Grand Rapids, are doing notable work in influencing boys to feel that all kinds of woodwork training are well worth while.

The impression created by carefully examining these hundred answered questionnaires is that neither teachers nor pupils find persuasive reasons for regarding woodwork training as either worth while for its own sake, or as leading to any important industrial opportunities.

COLLEGIATE INSTITUTIONS

The questionnaire replies in educational institutions of collegiate grade are much less encouraging and reveal almost no emphasis on woodworking for its own sake. Practically all institutions with engineering departments give a short course in making wooden patterns for foundry work, but it is really not a woodworking course, but rather a metal branch of industry.

Approximately half of the collegiate institutions in the United States are represented in the replies, so it is reasonably representative.

The following comment from an Ohio educator perhaps sums the matter up in a comprehensive way.

Thus we may say that while our regular engineering courses touch upon some particular phases of the wood industries, there is no specific course dealing with such industries as a whole. In fact, when we go a little deeper into the subject, we are forced to admit, speaking for this institution only, that there is nothing at present in our engineering courses that will direct the attention of students to such a field. A student may come here and absorb during his four years of college work a fairly definite idea of, say, the field of transportation, of manufacturing or production, of steam-power generation, of water-power development, of oil and gas production, or any other of the branch fields of engineering, but practically nothing that will direct his attention to engineering in the wood industries. This, however, is not to be wondered at when you stop to consider that any one of these fields is fairly well defined and that a student can enter one with a feeling that he can become a factor in that field and perhaps rise to a position of importance and responsibility. With regard to the wood industries, what specific advice could be given the student as to his entry into this field? What inducements can the wood industries offer to attract men with technical training? It seems to me that the whole matter hinges upon that proposition.

We had, ten or more years ago, a problem similar to this as regards foundry work, but the situation is now entirely different. At that time practically none of our graduates sought work in a foundry, and when one did occasionally stray into that field his treatment was not such as to encourage him to stay. In spite of this, however, there were managers with vision enough to see that the future progress of foundry practice would depend largely on technical knowledge, and with the courage of their convictions injected some of this young blood into their foundries. Today this has become a definite field for the young engineer, while the improvements made and prospects ahead are indeed gratifying. In this work the colleges are coöperating.

It is my own personal opinion that the wood industries should themselves take the initiative in this matter by providing inducements and places for technically trained young men, not with the idea of reaping immediate financial reward, but to sow the seeds for future growth and development. Another thing they might do is to make a survey of the field and acquaint the universities with its ramifications, its problems and prospects. I am sure the universities would coöperate to the fullest extent of their ability and resources once the field is defined and its problems crystallized.

A number of college administrators give various opinions regarding the value of choosing a career in the woodworking field. Many of these statements are from the academic group, but nevertheless they form a cross-section of educational views held in prominent walks of life.

Folks who can afford any training whatever seek something which they consider above woodworking.

Woodworking is the most popular of the manual arts. Generally speaking, the woodworker, on an average, is better paid than other crafts.

Vocational courses are for the most part only a phase of American gullibility. A proper system of shop apprenticeship and job training would be vastly superior pedagogically and economically than any school work, but the public does not believe this and organized labor will not allow it.

Shopwork and especially woodwork has not been elevated to its proper position in the college curriculum. Students try to avoid all courses that train them for future hand work.

The kind of education which requires that the student exert himself physically is not very popular. They desire to listen only.

Locally, furniture industry is noted as a low-wage, low-salary industry.

Engineering students do not feel that wood enters into the materials of engineering to an extent sufficient to warrant any appreciable amount of time being spent upon it.

Woodworking is old and simple to follow, and does not challenge the mind very much. I do not think courses of woodworking of any value.

We are operating our engineering department on the coöperative basis and find that in the woodworking industry here there is a marked shortage of material from which to produce woodworkers. The students lack sufficient vision to see the necessity as yet for learning thoroughly the art of woodworking.

School authorities do not seem to grasp the idea that it takes as many years, and as great an intelligence to produce a skilful mechanic as a Doctor of Philosophy.

Formal cut-and-dried model course has little educational value. Many teachers do not know how to develop a real vital curriculum in woodworking.

College students for engineering want to get by with lecture and information courses.

Our courses are very much in demand, and we never have enough places in our woodwork shop for those who wish to do this type of work.

There are several institutions that offer unusual opportunities in the woodworking direction, but the emphasis is more especially on forestry, in the School of Forestry of Yale University, and the New York State College of Forestry. The Bradley Polytechnic Institute (Illinois) offers quite a complete series of woodworking courses in diversified lines, but only includes the first two years of college grade, and is largely of the trade-school type as contrasted with the engineering branches. The Pennsylvania State College voices an optimistic view of situation, and has over three hundred students enrolled in a Wood-Products Production course.

There is no light demand in this college [says the reply] for woodworking courses. The Department of Industrial Engineering handles all courses entitled "shop," and such of these that are woodworking are always filled to capacity. It is the opinion of all the men who are furnishing this information that every manual-training course in the country teaches woodwork in some of its phases. The maximum bench space in one course is eight, but if more space could be obtained, the professor believes that as many as 200 Agricultural students would take this course in a year. The courses in industrial education are handled by the Industrial Engineering Department in coöperation with the School of Education, but as this school has a small number of students who are majoring in manual-training work some of the courses are not elected. During the coming year we expect to have pupils taking work in all of the courses listed.

The Ohio Association of Lumber Dealers have made an arrangement with Antioch College (Ohio) to establish a course in "Lumber," of ordinary college duration and leading to a degree. About twenty students are enrolled and the outline of studies embraces an analytical study of the materials, sources, fabrication, and marketing of lumber. Obviously this is more a business-administration course than an engineering training, but it offers some encouragement that the subject of woodworking is receiving more merited recognition.

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The results of such a questionnaire are obviously not thorough, but they doubtless express a fair average view of the attitude of educational administrators toward woodworking. The public schools use the work for manual training, but the pupil leaves his high school indifferent as to the possibilities in the woodworking field. Vocational and trade schools are making some progress in training craftsmen. Higher institutions are hardly aware that woodworking offers any executive, administrative, or engineering opportunities.

The people of the United States therefore proceed on their way blissfully unconscious of the fact that our wood resources are rapidly vanishing, and our present woodworking practice wastes on an average of two-thirds of the tree.

What are engineers to do about it?

Apprenticeship in the Building Trades

The Problems of Apprenticeship—Economic and Educational Background—What Is Being Done in Apprenticeship Training in the Building Trades

By DWIGHT L. HOOPINGARNER,[1] NEW YORK, N. Y.

THERE are two general points that I shall endeavor to make: first, to convey to you an idea as to the real problem of apprenticeship in the building trades, and, second, some idea as to what is being done about it. It is obvious, I take it, that any discussion of this subject without recognition of the basic economic problems of the construction industry and an understanding of sound educational philosophy would not be well grounded, and for that reason I am going to devote some time to this phase of the subject.

I should like also to ask you to let me speak not only as the director of the New York Building Congress, which is the occasion that brought me here since the managing director of its apprentice work is ill, but also to speak to you as the executive of the American Construction Council which is comparably organized from all component parts of the industry from the national standpoint to act on behalf of the construction industry nationally on economic, educational, and research matters. In what I shall have to say, may I also point out that before assuming my present duties I served as executive manager of one of the larger metropolitan building-trades employers' associations. I mention these things because what I shall have to say may in some cases be rather pointed and I want you to know that it is not just a theory but is based on experience in this field. I have honestly come to believe that the average person on the outside of the construction industry who discusses such problems as apprenticeship in the building trades is not as a rule in a position to think correctly about them because he does not have a basis of fact upon which to act.

There is probably no one in this room who will disagree with the statements as to the need for apprentice training, but in the past the intellectual agreement of most people on this question, including the manufacturing and employing interests as well as the professional, has been pretty largely academic in the sense that, with a relatively few outstanding exceptions, they have not been willing to pay the price for real apprentice training. I can truthfully say there is a great deal of talk about it, but relatively few persons are willing to give either the money or the time which is necessary to do something about it.

In that connection let me say that you hear a great deal about the restriction of unions in the building trades as to apprentices. I am in a position to say unqualifiedly that, generally speaking, the unions in this country in the building trades permit more apprentices to be trained than the employers are either, in some cases, able to take care of or, in other cases, willing to take care of. That may seem to you to be a broad statement. Let me add also that the fact that the employers are not willing or able to take care of apprentices is in most cases not the employers' fault, because the employer, usually called the contractor, must seek a job about as frequently as labor must. He gets a contract in one place one day, and the next few months his job is somewhere else. His work is not confined to a single place; it is where he happens to pluck off the lucky bid.

A—The Problems—Economic and Educational Background

The problem of labor supply in the construction industry cannot be solved as an isolated problem. It is tied up with labor supply in other fields, directly through the amount of labor involved, and indirectly through the stimulation of industrial and commercial activities generally and the operation of the construction industry itself.

Quality of workmanship and workers in sufficient numbers are very important factors in construction. Not only the matter of having sufficient labor available but the efficiency of labor and the craftsmanship put into the job from day to day are essential.

The dignity of craftsmanship and training for its proper pursuit have too long been neglected by industry and the public generally. But even a more fundamental consideration, if possible, is the lamentable but obvious fact that the training given the youth in the schools of the country has very largely ignored the most necessary element in all education—training for practical things in life which will equip the individual to make a livelihood and at the same time render real service to the community. In no industry are these facts more apparent than in construction.

Apprenticeship in the building trades is a problem of first importance to manufacturers, employers, labor, realty and building interests, investors, and home owners. Thus both quality of workmanship and workers in sufficient numbers are important in giving an adequate outlet for and satisfactory use of the product of the manufacturer of materials and equipment used in construction.

The money values of apprenticeship may be set forth in outline form as follows:

A—Value of Apprenticeship to Manufacturers and Employers

I—Quality of craftsmanship is of direct interest to the manufacturer of construction materials in that if such materials are not properly installed the manufacturer is at once made subject to censure for having produced faulty materials.

II—An adequate labor supply is necessary to furnish a satisfactory outlet for the product of the manufacturer, and hence has a direct relation to the general expansion of the basic industries related to construction.

III—Through furnishing an adequate outlet for materials it permits more normal development of markets and therefore helps to reduce cost of production.

IV—Likewise, these same factors enter into the value of apprenticeship to employers of construction labor—workmanship on the job, coördination of training with regular employment and operation of the industry, the furnishing of an adequate outlet for services of the employer, and the reduction of the unit cost of construction.

V—The coördination of apprentice training and employment stimulates regular and continuous operation of industry and of the employment of capital therein.

B—The Relation of Apprenticeship to Labor

I—The coördination of apprentice training and employment stimulate regular and continuous employment of labor.

II—The development of sufficient new and skilled mechanics is necessary to maintain the crafts for the future.

III—The high cost of homes affects the standard of living of the worker, such conditions often preventing even the industrious and thrifty worker, whether he be in the construction industry or in other industries, from becoming a home owner.

C—The Relation of Apprenticeship to Realty and Building Interests

I—An adequate supply of labor is directly related to initial costs in building construction, as reflected through both direct changes and costly delays.

II—The effect of trade skill in the proper installation of materials enters directly into initial costs.

III—Likewise the exercise of skill in the proper installation of materials directly affects depreciation and maintenance costs.

IV—A stabilized and efficient labor supply stimulates the healthy development of real estate over relatively long periods of time.

V—Future costs are also affected by quality of construction as it is reflected in the future value of the building as an economic proposition, particularly as to loss in the principal investment.

D—The Relation of Apprenticeship to the Community in General

I—The benefits of sound apprenticeship are thus distributed directly to the public in general and have a very real effect upon the whole community.

II—In the matter of housing alone its relations to rents and home ownership—one of the most serious problems confronting the country—requires the most constructive action.

The foregoing discussion admittedly limits itself to those aspects of apprenticeship that have to do more particularly with its value from a purely economic standpoint, and does not include

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such factors as the dignity of craftsmanship and consideration of the more fundamental educational nature lying back of apprenticeship training.

One of the greatest values, however, which comes from properly directed apprentice training is dignity of craftsmanship in general and the feeling of pride of craft on the part of the individual worker which comes from quality workmanship, and quality workmanship can come only from well-molded training and experience. Having a direct relation, as it does, to quality of workmanship, apprentice training is one of the most important factors that enter into better building, and I assume that it requires no further argument here to convey to you the economic value of better building in its many aspects. Thus craftsmanship brings benefits not only to the workers themselves but to the community also, as these mechanics through their labor do as much to bring ornament and beauty to the community as the painter's portrait, and just as truly contribute to stability and monetary values as the banker's bond.

It does not require a second thought, therefore, to see that any program having to do with the securing, training, and employment of workers in the construction industry cannot be solved apart from the economic problems confronting the industry. The whole conduct of the industry is enveloped in them, and the question of a proper labor supply in any of its phases cannot be divorced from the economic aspects themselves. This fact is particularly true of an industry so highly unstabilized as the construction industry has been up to the present time.

In fact, no more serious problem now confronts the construction industry than the fact that it is at present a highly seasonal industry, from which is demanded a volume of production exceeding its capacity on the part-time yearly basis. During the open season, construction demand exceeds the capacity for supply, if operations the past few years can be used as a gage. The remedy for this condition, in principle, is mainly to adjust demand to supply by spreading the demand over the whole year. This can be done to a far greater degree than has even been attempted, or than is generally considered possible. Thus, what appear to be high rates of wages in the building trades on the one hand and actual yearly earnings of the workers on the other hand often become confused in the public mind because of the fact that in about two hundred days, not infrequently in less, the worker must earn enough to keep himself and his dependents for the entire three hundred and sixty-five days. Similar hardships are placed upon the remunerative employment of capital in the industry.

The practical difficulties of stabilization, however, are not simple, and it would be folly to consider all of them as easy of elimination. But this makes the problem all the more necessary to solve in so far as a solution can be found.

In the matter of employment for the various trades of this industry, which of course is directly connected with the use of the respective materials with which these trades work, the peak load for all the trades does not come at the same time or necessarily the same season of the year. Thus a program to stimulate certain kinds of construction in order to give employment to labor and capital along certain lines may cause an over-demand for labor and materials in some lines unless the procedure is very carefully planned and proper safeguards are employed.

However, notable instances of major operations conducted during the fall and winter months during the past year or two with savings in construction costs ranging as high as ten per cent show the practicability of winter work an the benefits immediately accruing to individual owners and the public as well as to builders and labor on the job.

It is apparent, therefore, that the problem of apprenticeship is closely linked up with that of seasonal employment. The close connection of these two problems is seen in two important aspects: First, the proper determination of the real need for any additional mechanics in the industry must take into consideration the present conditions of successive employment and unemployment for the various trades and the effect of further stabilization of the operations of the industry throughout the entire year upon such employment. Second, before apprentices are trained there should be reasonable assurance of employment not only during the proper period within their apprenticeship but also when the full period of apprenticeship has been completed.

One aspect of this problem that too frequently is not recognized is the necessity for labor supply to be properly articulated with demand regularly from year to year. To develop a labor supply adequate to rush through an abnormal peak of activity which is only temporary, and then have more men trained for specific occupations than for whom work regularly will be available, will bring just as serious economic consequences to be reckoned with sooner or later as the failure to have sufficient skilled workmen required to care for a healthy and permanent program of construction.

Summarizing, then, as to the need, you must consider not merely the present requirements. If you are going to put a boy through a two, three, or four years' course of training, you must consider the general volume of business which that industry is going to have through a long period of years, and even though you grant, for the sake of argument, that there are at the present moment not enough apprentices in the building trades for present purposes, it may be that there are enough apprentices to take care of the future business of the construction industry because the construction business may have been having somewhat of a boom during the last few years. Are you going to have a surplus of workers trained for jobs that don't exist? That is the long-time viewpoint of volume of employment from the standpoint of business cycles for the industry. The second aspect of employment is the question of a job for any given boy, while he is indentured, through all the seasons of the year. As indicated, there have been boys brought into the field who have not had a job when they were training, to say nothing of the possibilities of a job later on.

So, you can't have a well-grounded apprentice-training program unless you consider along with it the question of the possibilities of employment. It can't be done; otherwise your program will blow up sooner or later.

These factors are important alike to capital and to labor. They directly reflect this, furthermore, in the making of apprentices an asset as early as possible rather than a liability for the employer, and likewise the training an actual asset to the apprentice as soon as possible.

Obviously, a movement so extensive in nature and so far-reaching in its possible results must be conducted through the coöperation of all elements of the construction industry—employing, manufacturing, professional, and labor interests. My statement that it requires the coöperation of all these elements to conduct a sound program is made advisedly, in that you may have a school that gives training, but if you don't have the coöperation of labor and of the employers you will not get employment. On the other hand, you may get employment, but you will undoubtedly not get the right training unless you have the coöperation of the educational authorities, particularly the public-school officials, in addition to what the technical and other schools do on the subject.

Any apprentice training in the building-trades program should include:

1 The articulation of apprenticeship needs and distribution of labor in construction activities.

2 The development of tested and approved courses of training for all trades and crafts, and the development of trade schools in coöperation with employers, workers, and school officials in the strategic localities.

3 Machinery for giving proper employment to apprentices.

4 Stabilization of employment for apprentices and other workers on as near an all-year-round basis as practicable so that they can stay at work after they have got a job.

A movement of this kind requires action on a national scale in addition to local endeavor. Recognizing that apprentice schools in most cases must be set up and administered locally so as to conform with local needs and conditions, national action is desirable for a number of reasons.

First, it is necessary to promote in a broad and effective manner the idea of apprenticeship among all elements affecting the industry in order to secure the active and wide-spread support required to insure permanent results.

Second, it is essential to bring together the various activities already under way in order to develop materials, methods, and experience of common value and to make them readily available to all.

Third, an adequate and efficient labor supply, since labor supply is a mobile thing, must be based upon national as well as individual local needs and resources.

Fourth, the relation of apprenticeship to unemployment and the need of assuring employment to apprentices on an all-year-round basis from year to year makes it necessary that apprenticeship needs, and conditions for training, be related to and assist in the stabilization of employment throughout the important construction centers of the country.

The results of such national action can be utilized by the various localities and branches of the industry as they deem best suited to their particular needs. Moreover a sound and permanent program on apprenticeship must be projected for years into the future and cannot be completed in a short time.

A national public opinion and general interest culminating in positive participation and support, is necessary, however, to solve such problems for the industry as a whole. One cannot be too dogmatic in saying that this problem is not merely an educational one—it is also distinctly an economic one.

B—What is Being Done in Apprentice Training in the Building Trades

I should now like to describe to you some of the efforts that are being made by different localities and other agencies to meet this need. I have already referred to the fact that the New York Building Congress is successfully conducting apprentice-training work. The Congress is made up of all component parts of the building industry—building investors and realtors, manufacturers and distributors of building materials, architects and engineers, contractors, labor, and related interests. The apprentice work is conducted through the Apprenticeship Commission of the Congress.

The Apprenticeship Commission is composed of thirteen members—three representing the New York Building Congress, five representing employers, and five representing labor. None of the Congress representatives is an employer in the building industry.

The Commission functions directly through the active coöperation of the employers and labor in the building industry and the New York City Board of Education. In addition, there is a Joint Apprenticeship Committee for each trade composed of three employers and three representatives of labor operating under the Commission to give special direction to the training and employment of the apprentices in their respective trades.

The Commission, created by the Congress in 1922, has the following basic purposes:

1 To induce a sufficient number of capable young men to enter the building trades.

2 To encourage employers to employ their quota of apprentices.

3 Through coöperative effort to provide each of these apprentices with steady employment through their apprenticeship period.

4 Through the collective effort of educational authorities, employers, and employees' associations to provide a thorough mechanical training that will insure and "carry on" for the future, craftsmen worthy of the name, and of great benefit to the trades and industry.

General principles for the training program are determined by the Apprenticeship Commission, and rules and regulations for putting them into effect are adopted and administered by it.

The work of the Commission, briefly stated, is first to get the employers and labor in each trade to agree on a program for the education and employment of apprentices in a trade. Then, through the Joint Apprenticeship Committees acting under the general supervision of the Commission, an analysis is made of each trade, after which, when found advisable, the courses of study are arranged.

Under the plans all the apprentices who are working at the trade attend evening vocational schools. These classes are in session for two evenings a week for two hours each, in the respective trades, the work being divided equally between shop practice and theory. The classes are held in coöperation with the Board of Education. The instructors are practical mechanics who know how to teach.

Accurate records are kept of the apprentice's progress both in the school and on the job. Any delinquency is immediately checked up and rectified if possible. No boy is kept enrolled if found wanting.

The work in the school is confined more or less to such technical studies and practical work as are, in the opinion of each joint committee, necessary for an all-round training.

As far as possible, and particularly in such trades as carpentry and joinery, upholstery, and painting and decorating, there is need for actual and practical work that takes on the conditions of trade experience.

These classes, requiring as they do considerable equipment, are maintained at great expense. Practical work is to be ultimately provided in so far as it is found necessary for the proper training of apprentices.

The Board of Education has set aside a sufficient sum in anticipation of the growth of the New York Building Congress apprenticeship work during the coming year, to care for their phase of the work.

This is the record so far by the Apprenticeship Commission of the New York Building Congress since 1922:

Each trade has the following apprentices:

Carpentry and joinery	1,451
Painting and decorating	223
Electrical	535
Upholstery	92
Plastering	470
Bricklaying	1,407
Plumbing, Queens	80
Granite cutting	66
	4,324

At present there are the following number of apprentices in attendance in the schools:

Carpentry and joinery	572
Painting and decorating	147
Electrical	331
Upholstery	81
Plastering	319
Bricklaying	889
Plumbing, Queens	70
Granite cutting	43
	2,452

The school enrolment has been retarded because of lack of facilities. Within the coming year, and as soon as accomodations are completed and teachers available, all apprentices will be in attendance. There are at present the following number of classes in each subject:

Carpentry and joinery	20
Painting and decorating	4
Electrical	19
Bricklaying	16
Plastering	8
Upholstery	4
Plumbing, Queens	3
Granite cutting	2
	76

There are other local training programs such as the one in Boston and the one in Paterson. There is also the one in Cleveland which I had the opportunity of helping to start and which, incidentally, began with one or two individual trades and is growing and widening to cover the entire industry, a very conservative but apparently a very sound development.

The Cleveland Building Trades Apprentice School is conducted by the Cleveland Board of Education in coöperation with the employing contractors, building-trades labor, and the Federal and State Boards for Vocational Education, together with the assistance of building-supply dealers.

The school operates under the Federal Smith-Hughes Law, according to which the Federal Board for Vocational Education contributes a certain amount for instructors' salaries, which is matched by equal amounts by the state and local boards. The industry itself, including the building-supply people, employers, and certain of the unions, also contribute toward the support of the school.

The school functions through a General Committee on Apprentice Training which is made up of one representative from labor and one from the employers for each trade which gives apprentice training, one from the Building Trades Employers' Association and

two representatives from the local Board of Education. In addition, each trade has a "Trade Apprentice Committee" which is composed of representatives of both labor and of employers. The trades having such committees at the present time are:

- Bricklayers
- Carpenters
- Electricians
- Painters
- Plumbers

These are identical with the trades which have schools in operation. The attendance, with the number of instructors at the present time is as follows:

	Instructors	Apprentices
Bricklayers	2	218
Carpenters	2	224
Electricians	1	126
Painters	1	190
Plumbers	1	150

All of the apprentice boys are actually employed at the trade and spend four hours per week in school, for which time they are paid by their contractors.

The teachers themselves go to a teachers' training school four hours per week to receive instruction in the art and methods of teaching. All teachers must have had practical experience in the trade which they teach.

Thus both from the standpoint of the teacher and the material taught, the boys receive instruction in both the theory and practice of the trade.

In Cleveland, as elsewhere, those who are in touch with the work being done to develop apprentices in the building trades through the coöperation of employers, labor, and public schools feel that these efforts not only make for a better standard of work in the building trades but also develop more cordial relations and better understanding between employer and employee.

There are, of course, other types of schools which give apprentice training in the building trades. Some of these are privately endowed trade schools such as the Boston Trade School for Boys, and the David Ranken, Jr., School of Mechanical Trades in St. Louis. There are also the Cass Technical High School, of Detroit, Mich., and the Dunwoody Institute in Minneapolis. In some cases, industries have carried on work on behalf of the industry as a whole, as, for example, in the tile industry.

Obviously, the outstanding conclusion is that the principles on which the apprentice schools operate and their methods of support vary greatly. Generally speaking, what has been done is, with a few outstanding exceptions, the result of sporadic impulse. This shows the need for general information on and the development of sound principles and methods that can be adapted to local needs.

The readiness of various localities to put into actual effect a program of apprentice training has been fairly demonstrated but the knowledge of exactly what should be done and how to do it, and the securing of proper support in each case, remain unsettled problems. Most of the apprentice schools for the building trades thus far under way are at the present time handicapped by lack of general instructional materials, methods, and standards. All of these of course must be adapted to local conditions.

Generally speaking, at the present time apprentice training in the building trades is in the position that the public-school systems of the country would be if they had no well-developed and reasonably well-proven type of textbooks, teaching methods, or standards to use for instructing the boys and girls of the country. The building trades must develop such methods and standards for instructing their apprentices or continue in the haphazard manner in which they now find themselves, with the enormous loss in time and efficiency and in actually misdirected expenditures of money that are taking place in some cases. The American Construction Council has set up a research program on teaching materials, methods, and standards. Certain localities, such as New York City, have done good work in their own field. Likewise, the tile industry has a highly developed course of study. But, for the industry as a whole, the job yet remains to be done.

My own personal conclusion from close contact with apprentice-training work in such localities as Cleveland and New York through the schools there, as already described, and national acquaintance with the problem through the American Construction Council and its allied agencies, is that any apprentice plan to be permanently successful both in training and in securing employment for the apprentices must have the general coöperation of labor and public schools locally, and to this must be added the support of such agencies as the Federal Board for Vocational Education and the industry nationally. The problem has certain local aspects and certain national aspects, certain public aspects and certain private aspects, and these all must be properly evaluated and dovetailed with each other.

These programs must be eventually linked up in some way or another with the public-school systems throughout the country and not depend alone for their support and permanency on the initiative and fluctuating impulses of private industry. It should constantly be borne in mind that the maintenance and support of an apprentice system in each industry is both a duty and an economical asset for every community.

In closing, it is perhaps well to bear in mind what the purposes of education by industry are, and in this connection I should like to give you an extract from a recent book by the speaker, entitled "Labor Relations in Industry," which reads as follows:

> Education on the part of industry has three major purposes to perform:
>
> 1 To give technical efficiency to the worker;
> 2 To develop a sound industrial citizenship;
> 3 To cultivate appreciation of relative values in life.
>
> In performing these functions it should not conflict with the aims and machinery of the general educational system. It should be in harmony with them, yet not try to perform the duties of the public-school system. At the same time, it must supplement the training secured in the public schools, whether its workers leave the schools with or without a substantial training. In brief, industry must train its workers to meet its peculiar needs in economic efficiency, supplementing, when desirable, the worker's general education, and assist in the application of the worker's entire educational equipment so as to utilize to the best advantage the fundamentals of all education. This means it must assist within its own sphere in the education of the individual for participation in the enjoyment of the legitimate activities and pleasures of life, both within and without the industry. It can no more ignore than it can supplant the education of the public schools and life itself outside of industry.

A Self-Supporting Apprenticeship System

MONTHLY figures compiled by the regular cost-accounting department of the Marion Steam Shovel Co., Marion, Ohio, prove that this company breaks even financially on its apprentice courses. At this plant there is no separate department in which the boys are given a preliminary training; they are immediately placed on a regular production machine in some department of the shop, and are transferred from department to department as they progress. In each department, they are assigned successively to the different machines to finish the work routed to those machines. In routing the work, no thought is given to the operator, the only consideration being the ability of the machine to perform the different operations required.

Fair wages are paid to the apprentices, but, as in any other shop, the rates are somewhat lower than those paid to men or boys who are operating similar machines but are not learning a trade. On the basis of the work actually performed, it has been estimated that the apprentices, taken as a whole, are worth a wage equal to the average rate paid in the various departments, because the apprentices turn out as much work as the average man. But, as the average rate paid in each department is higher than the apprentice rates, for every hour an apprentice spends in a given department the company saves the difference between the average rate of that department and the wage paid the apprentice. In figuring the costs of running the apprenticeship system, this difference is credited to the system.

On the other hand, should it happen that an apprentice takes six hours to do a job that a regular machinist could turn out in four, two hours at the average rate is charged against the apprentice department and also the regular shop overhead cost for two hours of a man's time. Then, too, for every hour that a boy spends in school receiving instruction in shop mathematics, mechanical drawing, etc., the apprentice rate for one hour is charged against the apprenticeship system.—*Machinery*, December, 1925, p. 326.

The Safety of the Zeppelin Airship

A Survey of the Possible Dangers and Risks That Might Be Encountered by Airship of the Zeppelin Type, and of Means of Overcoming or Avoiding Them—Data on the Careers of the 115 Airships Constructed by the German Zeppelin Company

By E. A. LEHMANN,[1] AKRON, OHIO

IN SPEAKING of the safety of the Zeppelin airship, the question arises at once whether all the possible dangers and risks which an aerial vehicle might encounter are sufficiently known to enable a complete survey. The question can be answered in the affirmative, since the 25 years of airship navigation have furnished ample opportunity for experience and study of all the natural conditions under which such vessels may have to operate, with the exception of tropical cloudbursts and of tornadoes.

The principal dangers are the following:

I—*Meterological Phenomena*

1 Winds and gales
2 Electrical phenomena, thunderstorms and squalls
3 Rain, snow, hail, sleet
4 Fog
5 Extreme cold
6 Extreme heat
7 Influence of combinations of weather phenomena and general effects.

These are the external influences which the airship must be able to withstand or avoid.

II—*Human Incompetency*

1 Faulty design and construction
2 Incompetency in operations and maintenance.

This heading includes the dangers of fire and mechanical damages in flight or on land.

In dealing with the subject the author proposes to consider first the possible effects of the forces of nature on a fully modern and powerful airship manned by a competent crew, incidentally explaining the various technical means and some of the rules of operating science which have been established from experience.

Winds and Gales

First consider an ordinary strong wind or gale. For the safety of the airship, as long as it is in the free air a gale as severe as any ever recorded does not constitute a danger in itself, and the stresses for the ship are generally no greater than in a moderate breeze.

The usual fallacy by which many people are deceived in this respect results quite excusably from observations of the tremendous forces and destructive effects which the air in motion, that is, the wind, can exert on objects fixed on the ground, such as the uprooting of trees, the unroofing of houses, etc. But an airship in flight is not a fixed object, it is simply floating as a particle in the surrounding air. If during flight the propellers were entirely stopped a person on board the airship would feel no wind at all, even if a full gale were blowing at the time, when the ship might be carried along like a cloud with a terrific speed relative to the ground.

Now, since the only forces which an airship can possibly oppose to its movement along with a wind or gale are those furnished by its own propelling machinery, it results that the stresses which the vessel might possibly experience cannot normally exceed those created by this known amount of power, irrespective of the force of the wind, which may be simultaneously experienced on the ground.

The only additional forces or stresses to which an airship can be subjected in the air are accordingly not due to the primary force of the wind or gale as commonly conceived with respect to the ground, but only to irregularities in the wind. Here again a fallacy resulting from observations on the ground often leads to misconceptions. Due to the presence of hills, mountains, and other obstacles the wind is almost always turbulent and very irregular at or near the ground, so that the accelerations or decelerations of the masses of air felt by an observer on the ground are incomparably greater than those in the free air.

Summarizing, the "wind" by itself, be it a gentle breeze or a hurricane gale, has no effect whatsoever on the safety of an airship in flight. Its irregularities, however, which are usually slight in higher altitudes, cause certain stresses due to accelerations or decelerations of the masses of the airship, but these can be taken care of by the strength calculations. On the ground, while being moored to an anchorage or while landing, an airship may of course be subjected to greater forces. But these would again not be due to the velocity of the wind itself, as long as this is steady, but to the much greater turbulence near the ground. It is an established fact that landing and mooring an airship to the ground or to a mast in a high wind of, say, 30 to 40 m.p.h. offer no difficulties as long as the wind is steady. These steady conditions prevail normally over flat lands, and especially near and over the water. If, however, the country surrounding a landing field is hilly, the air will be so full of whirls, eddies, and gusts that many normally easy maneuvers will be quite impossible. The remedies lie in the selection of suitable localities for landing fields, in the thorough training of the personnel, and finally, in rare cases, in the postponement of the landing or ground maneuver.

The start of an airship from the ground or mast is possible under almost any condition of wind and weather.

Docking maneuvers, or the taking of an airship into or out of its hangar, are limited to winds below 20 to 25 m.p.h. for rotatable hangars or winds in the direction of the hangar axis, and of 6 to 8 m.p.h. in the case of cross-winds.

A measure which provides complete safety for an airship in view of these limitations consists in the carrying aboard of a sufficient amount of engine fuel for contingencies, enabling the ship to either ride out a storm in the air or to reach an emergency landing station located at a suitable distance from the terminal proper.

Thunderstorms and Squalls

Thunderstorms are characterized by the most irregular currents of the air within and in the immediate vicinity of their cloud formations. There are two kinds of thunderstorms, which, although they are alike as to the principle of their origin, are very different as to intensity and area of influence.

The most harmless and, fortunately, the most frequent form of thunderstorm is the so-called local one. It is primarily due to the unequal absorption of the heat rays of the sun by the different materials composing the earth's surface. The rising current thus established by the unequal heating of the adjacent air, continues to exist as long as the conditions do not materially change. The ascending masses of air encounter colder temperatures and lower pressures at higher altitudes, whereupon their moisture condenses and their presence becomes visible by the formation of a cumulus (the so-called "good-weather" cloud). Once this cloud has been formed, the phenomenon proceeds more or less continuously, and the incipient thunderstorm may drift from its place of origin with whatever little wind there may be.

It is obvious that in this stage the intensity of the vertical motion can be but very small, and that it is entirely negligible for airships and the altitudes commonly navigated. The stores of "veritable fountains of uprushing air in the clear atmosphere" belong in the category of sea-serpent tales. Scientific deductions and practical experience make it probable that the velocities of the convection currents in question are not greater than about one foot per second for altitudes up to a thousand or fifteen hundred feet.

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Presented at a meeting of the Metropolitan Section of The American Society of Mechanical Engineers, New York, November 24, 1925. Abridged.

In much higher altitudes, however, there may sometimes develop considerable vertical velocities—25 or more feet per second—and the well-known so-called "hail towers" or cumulus clouds which sometimes form in very high altitudes and build up rapidly, are due to extreme conditions of this kind.

The second category of "thunderstorms" presents a different aspect. They originate simultaneously along a line often extending for hundreds of miles, if and when great masses of cold air, coming from the north, meet with relatively warm air, especially in summer in the often-overheated areas of the great continents. At this dividing line, which is called the "squall line," the warm air is forced upward by the cold air wedging itself under it and causing great disturbances of the original balanced condition. On many points of such a squall line, especially where the formation of the ground, that is, hills or mountains, is favorable to the initiation of ascending currents, squalls and squall clouds begin to form through the condensation of the moisture contained in the ascending air. The typical squall cloud is discernible from great distances by its dark color and distinctly peculiar shape.

A thunderstorm is nothing more than an intense form of squall, and the moment of the "breaking" of the clouds, that is, the beginning of the rain burst and the setting up of the greater intensity, can after some experience almost always be accurately predicted from the changes in the formation of the clouds.

Although there are numerous small eddies and whirls inside a squall or thunderstorm cloud, there is, with the possible exception of some extremely rare cases, normally nothing of a big, uniform, rotating movement of air currents—in other words, nothing corresponding to the popular conception of a "twister" capable of setting up considerable forces. From past experience we may expect vertical components of air currents of about 6 m.p.h., and in exceptional cases possibly up to 15 or even 20 m.p.h. in the immediate vicinity of and inside such clouds. But there is nothing in such velocities to threaten the safety of a well-designed airship. Only in very high altitudes not normally navigated have higher velocities of 30 or more miles per hour been observed.

With regard now to the safe navigation of airships under such circumstances, the prime rule is to stay out of and away from the clouds. It would be possible to sail right through the middle of a thunderstorm cloud, even at a higher altitude, without fear of a failure in structural strength, and it has been done, but the elementary rule is strictly to stay out of any isolated cloud, even an evidently harmless one.

In the case of the so-called "local" thunderstorms described at the beginning, it is of course the rule to fly around them—that is, to pass them on one side—which is easily possible on account of their comparatively small dimensions and slow motion.

With line squalls and squall-line thunderstorms, if they should be too widespread to be circumnavigated as a whole the rule is to break through the chain at one of the usually numerous spots at which they are not fully developed. These "holes in the wall" are discernible in daytime by the character of the clouds, and at night by the absence or low intensity of the lightning.

It has been abundantly established by experience that any squall or thunderstorm, as long as it has not reached the full "working stage"—which, as stated, can be readily recognized—is absolutely harmless and may be safely passed on its underside in not too close vicinity to the lower edge of the clouds.

In any event, even if an airship is compelled to go through or under a "working" thunderstorm, the above explanations ought to show that there is nothing in the nature of the air currents to endanger the safety of the vessel, if only the commander sticks close enough to the ground and knows when to expect and how to meet the changing air currents in order to preserve his proper and safe altitude. It is obvious that near the ground there can be only more or less horizontal winds of different directions, since the air cannot be sucked out of or pumped into the earth, so over flat territory there is no reason at all to worry about even the worst imaginable squalls or thunderstorms.

Over hilly country or between mountains it requires experience and skill on the part of the commander and a perfectly trained and disciplined crew to keep the airship close to the ground and under complete control as to altitude. In any event the experience gained from hundreds of thunderstorm flights has conclusively shown that with proper observance of the rules which have been followed in the past, any modern airship should be completely safe in every respect.

There is only one phenomenon of this category which has not been the subject of sufficient practical study, experiment, and experience, and that is the tornado.

The mechanics of the origin of tornadoes are not properly known as yet, although it is evident that they belong essentially in the same category as squalls and the thunderstorms. Their well-known extremely destructive effects on objects fixed on the ground permit drawing the conclusion that in their center the air pressure may be extremely low, and it follows that an airship striking this center would probably be destroyed by the bursting of its gas cells, especially in the case of a powerful tornado of comparatively small diameter.

On the other hand, if an airship were to run into a large-sized tornado at or close to its outer edge, it seems possible from the experience available with the forces of the air that it might escape unhurt. The rule will of course be to avoid tornadoes by all means, which is always possible during the daytime. At night they are very rare, but possibly not always readily recognizable from the air.

An adequate weather-reporting organization, which in any event would be necessary to give reports to the airships in flight regarding the squalls and thunderstorms approaching the route, would effectively close this gap. An elaborate system has been prepared by the U. S. Weather Bureau and is ready for introduction.

Nothing has been said as yet regarding the effects of lightning striking an airship, and of other phenomena of atmospheric electricity. That a Zeppelin-type metal airship is perfectly safe from any danger from these sources, even with 100 per cent hydrogen inflation, provided that certain rules in its operation are faithfully observed, is a fact which has been proven by dozens of practical cases.

These rules, briefly, have as their object the insuring that no hydrogen gas shall escape from the gas cells of the airship during periods within which lightning might strike it.

As long as these rules are observed, even the hydrogen ship is safe, because the airship body in itself is within reasonable limits always at the same potential (voltage) with the surrounding air due to the engine exhaust gases constantly carrying away any excess of electrical charge. Further, the masses of metal of the structure, which form a continuous "Faraday" cage around the whole of the ship, are amply large enough to take up safely all of the amperage transmitted to it by any lightning, until it can be discharged again through the streams of engine exhaust or from other safe points.

As to the safe absorption of the enormous concentrated charge at the point of entrance of a lightning stroke, experience has shown that the arrangement of the structural parts in a Zeppelin airship provides a sufficient cross-sectional area or bulk of metal at any of the possibly exposed points to prevent the melting or heating up of metal to a dangerous degree. Further, the Zeppelin system provides for a separation of the possible points of entrance of lightning which necessarily are on the outer skin from the inner skin of the gas cells, within which the gas is contained, by an interspace of sufficient depth forming a protective layer of air, which, if considered worth while, could for additional protection be filled with inert or fire-extinguishing gases.

As stated above, experience with dozens of Zeppelins struck by lightning has shown that with the combination of these features even a hydrogen-filled metallic airship is perfectly safe from lightning. It goes without saying, therefore, that a helium-filled airship is altogether lightning-proof.

Rain, Snow, Hail, Sleet

The next category of weather influences includes rain, snow, hail, and sleet, or, briefly, what meteorologists call precipitation.

Rain, the most common of these phenomena, has the least disagreeable influence on an airship. Since the outer skin of the ship is doped waterproof, it does not absorb any considerable amount of water for any appreciable length of time. It can be demonstrated by calculations—which have been borne out by practical experience of thousands of flights—that the forces exerted temporarily upon the airship in this way by any rainfall possible of occurrence in

the temperate zones can be easily overcome by any modern airship.

With regard to tropical cloudbursts, if future experience should show it to be necessary, perfect safety could be provided by increasing the percentage of ballast reserve, which could be easily done with modern exhaust-condensing and ballast-recovering equipment.

Snow usually exerts much less influence than rain, since practically no dry snow will stick to the slim, smooth body of a fast-flying airship. If occasionally the snow should be wet, however, the simple rule is for the airship commander to change temporarily to another altitude where the snow will become dry. Besides, the carrying of an adequate ballast reserve in winter offers no difficulties, since the lifting power of an airship is very much greater in winter than in summer. This latter fortunate circumstance is generally responsible for the fact that the safety of an airship with a skilled crew is not less in winter than it is in summer weather.

Hail in itself, even the worst kind, is of no danger to airships. The strength of the fabric outer cover in combination with its elasticity and resilience explain this, and in fact there is no case known where damage has been done to a Zeppelin airship by hailstones.

Sleet may in certain rare cases create very disagreeable situations for airships. It can easily be avoided by an airship in flight by simply rising to a slightly higher altitude. It can, however, although the case might be very rare, positively prevent a landing temporarily, since the possible accumulation of an ice coating on the surface of an airship may exceed in weight the amount of ballast ordinarily carried.

Fog

Fog of course offers no difficulties for an airship in flight. The situation is entirely different from what it is for an airplane, for which fog constitutes one of the greatest dangers because of its limited facilities for navigation and the always imminent possibility of an emergency landing.

The navigator on board of an airship can fully command all the known facilities and methods of ocean navigation, with instruments and additional apparatus which are in some respects even more efficient for air navigation. He has no rocks, shoals, nor icebergs, and very few other vessels, to consider, and he need not land his ship unless he wants to.

Even on the best-equipped flying field a fog landing is an extremely dangerous undertaking for the airplane. The airship can effect such a landing at any place and at any time because it can reduce its horizontal and vertical speed to zero if desired, and it can locate exactly its landing spot by acoustic or radio devices.

Normally an airship will not have to delay its landing on account of fog as the ocean steamers frequently have to do. Only in the few rare cases where fog is accompanied by a strong wind might the airship commander prefer to postpone the landing in order to avoid any risk and insure complete safety for the ship and its passengers.

It is a fundamental rule for Zeppelin design and operations that a certain surplus of fuel must be included over and above that needed for the maximum scheduled duration of the flight, to provide an adequate emergency fuel reserve for such possible delays in landing or for prolonged flight to another station. Any or all the aforementioned weather phenomena might make a landing at a certain place temporarily inadvisable, but ship and men will always be completely safe as long as this rule is conscientiously observed.

Extreme Cold and Heat

Cold weather, although it brings a number of inconveniences, does actually increase the safety of airship by making possible a much better lift. This increase in lifting power, which may amount to 10 per cent more in winter than in summer, makes it easily possible to install protective devices of various kinds to safeguard the normal operation of all parts of the airship even under the most extreme conditions of low temperatures.

Extreme heat, on the other hand, has the opposite effect, decreasing the lift, and there might ultimately be a point for a ship where it might not have reserves enough left to undertake a certain flight with safety. However, since every airship should be designed for its particular purposes and range of operations and should not be used for any flights beyond its capacity, it follows that with competent management and proper care airships are completely safe in this as in every other respect.

Combined Effects of Weather and Sun's Rays

In concluding this section of the survey and in order to make it fairly complete, something should be said concerning the influence of the sun's rays on an airship and the combined effects of this and all the elements of weather previously described on the deterioration of the materials of which a Zeppelin airship is constructed.

Since there is no material in existence which is not subject to deterioration, the principal and by far most important requirement for the safety of any structure—and especially of an airship—lies in the constant supervision, inspection, and control of all its parts and the complete accessibility and ease of replacement of any of them.

The Zeppelin airship has been laid out and developed with particular reference to this point. In the modern Zeppelin design there is practically not a single part or corner which is not permanently accessible and where repairs, if necessary, cannot be made instantly and effectively, even in flight.

The influence of the sun's rays is of a twofold nature as far as the safety and operations of an airship are concerned. On the one hand the chemical effects of the sun's rays, and especially those of the tropical sun, in combination with repeated wetting and drying or freezing and thawing, cause a gradual deterioration of the fabric which forms the basic material for the outer cover and gas cells of the ship. Experience has shown, however, that this does not result in a material decrease of strength. It has never been necessary, for instance, to replace an outer cover of a Zeppelin airship, although formerly the known methods of protection of the fabric by dope coatings or metallizing were not used, and although such ships have been in service for four and five years. Later and recent developments, which were first tentatively tried on the *Los Angeles*, have been so very promising, that we can expect the future type of outer cover—which will be a composite structure consisting of cotton fabric as a base with various layers of metal and dope coatings—to last in any climate with proper care almost as long as the purely metal parts of the ship's framework.

With regard to deterioration of the metal structure, it may seem paradoxical but it is a fact that there has been more trouble from corrosion of metal, especially of the very thin lattice work, than from the fabric parts just mentioned. However, with modern detail design, constant supervision, and proper care it can be safely assumed that the Zeppelin structure will keep in good condition in any climate for at least five years. The principal advantage of the modern Zeppelin design with regard to these factors is the complete accessibility of every part from both inside and outside, and the resulting possibility of constant supervision and easy refinishing or replacement.

Considering again the sun's rays, it should be noted that they act indirectly upon the lifting gas contained inside the airship. Since any difference in the temperature of the lifting gas from that of the surrounding air is a disadvantage, and since especially the so-called "superheat" may attain a very inconvenient height, particularly in hot climates, the Zeppelin system has introduced besides other heat-protective means an insulating layer of air—the ventilated "jacket space" between the inner and outer skin—which has been found to be almost 100 per cent effective. The greatest, almost invaluable advantage of this feature is, however, that it makes possible complete accessibility at any time to any part of the gas cells, enabling immediate detection and repair of any leakage, and thus increasing the safety of the modern Zeppelin many times above that of any other known type of airship.

Careers of the 115 Airships Built by the Zeppelin Company

The second part of this review of airship risks deals with the dangers resulting from the natural imperfection of all human engineering work and the equally unavoidable lack of complete efficiency in operating ability and managemant.

In both these fields, although the fact is unknown to many

people, there exists a vast amount of experience today since the airship industry is practically as old as the automobile industry.

Table 1 shows *that not a single one out of the 115 Zeppelin-built airships has been destroyed by a storm in the air*, and that only two were lost on account of engineering mistakes in the earlier times.

It is of course just as impossible for the designer of an airship to produce an inherently indestructible craft as it is for the automotive engineer to build a foolproof automobile or the naval architect to furnish an imperishable sea vessel. It is always and everywhere necessary that there be a governing mind with the vehicle to keep it in proper working order and to guide and use it expertly with full consideration of its particular qualities. And, exactly as in all the other fields of transportation, it is in this direction in the case of the airship, that most of the mistakes have been made. The lessons, however, have been learned and the list of "things *not* to do" in the operation of airships seems to be fairly complete at the present time.

TABLE 1 ULTIMATE FATE OF THE 115 AIRSHIPS BUILT BY THE GERMAN ZEPPELIN COMPANY AND OPERATED BY GERMAN PERSONNEL

	Number	Per cent of total
I—Ships Put out of Commission While Intact		
1—Obsolete and Dismantled after Successful Career		
The Zeppelins LZ 1, *Hansa*, *Sachsen*, Z 1, *Ersatz* Z 2, Z 3, Z 4, Z 12, LZ 72, LZ 87, LZ 93, LZ 97, LZ 98, LZ 101, LZ 103, LZ 107, LZ 111, L 11, L 13, L 25, L 35	21	18½
2—Surrendered to Allied Governments after the Armistice		
L64,[1] L 71 to England; L 72, LZ 113, *Nordstern*[1] to France; L 61, LZ 120, *Bodensee*[1] to Italy; L 30 to Belgium (in parts); L 37 to Japan (in parts)	10	9
3—Destroyed by Crews in the Hangars after the Armistice		
L 14, L 41, L 42, L 63, L 65, L 52, L 56	7	6
Total	38	33½
II—War Losses		
1—Shot Down by Enemy		
(*a*) Hit by incendiary projectiles from artillery or airplanes during raids or scouting trips and burnt in the air (crews dead with few exceptions): L 7, L 21, L 22, L 23, L 31, L 32, L 34, L 39, L 43, L 44, L 48, L 53, L 59, L 62, L 70, LZ 37, LZ 77	17	
(*b*) Heavily damaged by artillery, stranded or wrecked in landings on return from flight, mostly without injury to crew: L 5, L 8, L 12, L 15, L 19, L 33, L 55, Z 5, Z 6, Z 7, Z 8, Z 10, LZ 34, LZ 35, LZ 39, LZ 79, LZ 81, LZ 85, LZ 95	19	
	36	31
2—Landed in Neutral or Enemy Territory		
(Due to exhaustion of fuel, ships dismantled, crews interned or prisoners) L 3, L 4, L 20, L 38, L 45, L 49, L 50	7	6
3—Destroyed by Enemy Action in the Hangars		
(No losses of lives) Z 9, LZ 38, L 54, L 60, L 46, L 47, L 51, L 58	8	7
Total	51	44
III—Losses Due to Inexperience in Operating		
1—Burnt in the Hangars		
(Through carelessness with gasoline or hydrogen—few injuries) LZ 6, L 6, L 9, L 18, L 17	5	4½
2—Damaged in Ground or Hangar Maneuvers and Dismantled		
(No injuries to crew) *Viktoria Louise*, *Ersatz Deutschland*, Z 11, L 24, L 57, LZ 90	6	5½
3—Damaged in Landings		
(On account of navigational mistakes, and dismantled—few injuries to crew) LZ 2, LZ 4, *Deutschland*, Z 2, first *Ersatz* Z 1, second *Ersatz* Z 1, L 1, L 16, L 36, L 40, LZ 74, LZ 86	12	10½
4—Burnt in the Air		
("Valving" ship struck by lightning—crew died) L 10	1	½
Total	24	21
IV—Losses Due to Inexperience in Engineering		
1—Use of Rubberized Gas Cells		
The *Schwaben* was burnt while moored on the landing field due to a spark caused by frictional electricity set up by the flapping and rubbing of the rubberized fabric. (No loss of life)	1	
2—Insufficient Ventilation of the Power Cars		
The L2 was burnt on a trial flight during ascent from ground due to hydrogen finding its way into a power car in coincidence with a backfiring motor. Crew died	1	
Total	2	1½

Summary	Number		Per cent	
I—Ships out of commission, while intact	38	89	33½	77½
II—War losses	51		44	
III—Inexperience in operating	24	26	21	22½
IV—Inexperience in engineering	2		1½	
	115		100	

[1] Still existing, remainder wrecked by inexperience.

Table 1 shows that $33^1/_2$ per cent of all Zeppelins came to a "normal" end of their career, and that 44 per cent were lost through enemy action. Of these, no doubt the majority could have been saved if helium had been available and there had been more time for the training of the crews.

The conclusion for peace-time conditions, however, is that *at least $77^1/_2$ per cent* or 89 of the 115 Zeppelins built might still exist and operate today.

The remaining $22^1/_2$ per cent of the ships were lost due to inexperience, and 95 per cent of these due to lack of operating experience. (This latter figure is a most significant indication of the importance of the proper training of the operating personnel.) There were only two cases of engineering mistakes, and these led to the losses of ships only through the unfortunate coincidence of several factors. It is evident that these mistakes will not be repeated.

Since not a single one out of 115 Zeppelin airships failed in strength, although the majority of them were subjected at least once during their careers to the most extreme stresses, it is safe to assume that no future Zeppelins need be lost for reason of inexperience in engineering.

There are still remaining 21 per cent of what might appear to be "normal" losses. It is easy to demonstrate, however, that almost all of these cases were due to causes which in the future can be and should be avoided.

The category in question comprises 24 cases. Six of them, those cited under III-1 and III-4, can at once be discounted, since they occurred only through plain disobedience of strictly established rules and even then could not have happened if helium had been used.

Of the remaining 18 cases it is probable that some of the early ones simply had to happen once, since at the beginning there existed no experience at all to guide the operators. Altogether 8 ships belong under this heading. It is clear that they can be discounted for the future.

The remaining 10 cases are due to lack of proper training of the airship commanders and crews, who under the pressure of war could be given no more than half the necessary education (in some cases only 3 months!). Investigation of these cases reveals the fact that none of them would have happened with properly experienced crews.

Little Probability of Losses of Zeppelin Airships in the Future

The general conclusion from this analysis is, therefore, that with the present status of Zeppelin engineering and granted a properly educated and conscientious operating personnel, there is very little probability of any further losses of Zeppelin airships in the future.

The introduction of the non-combustible helium gas has most effectively minimized the fire risks. They may be taken as almost zero even today, where gasoline engines are still the only practicable source of motive power, provided that at least the same ordinary care is given to the handling of gasoline by a well-trained crew as in the case of any motor car.

With the substitution of heavy-oil engines using a fuel of very low flashpoint in the place of the present gasoline, this last potential source of a danger from fire on board of airships will be completely eliminated.

The loss of the *Shenandoah*, no matter what detail reasons the investigations may reveal, belongs to the category of cases which have to happen once for the sake of gaining experience.

The activities of purely commercial airships (Zeppelins only) show that out of nine ships four were lost in the pioneering period 1910–1912, before sufficient operating and engineering experiences had been gained; that thereafter only one ship was wrecked by a naturally inexperienced training crew after a successful career; that no lives were lost and not the slightest injury to passengers occurred in the whole history, although these ships have been altogether about 5000 hours in the air, made about 4000 landings and starts, and carried about 40,000 passengers; and that, discounting the initial losses of ships, a fully satisfactory service for almost three years' time has been realized from a commercial Zeppelin-airship fleet with complete safety to passengers and crews, and this in spite of comparatively inefficient airships and little experience.

The 1925 A.S.M.E. Student Prize Award Paper

Some Attempts to Measure the Drawing Properties of Metals

By WILLIAM S. MONTGOMERY, JR., and E. RAY ENDERS, JR.,[1] STATE COLLEGE, PA.

As a CONTRIBUTORY part of the program outlined for research pertaining to the cutting and forming of metals, headed by Mr. B. H. Blood, Chairman of the A.S.M.E. Special Research Committee on the Cutting and Forming of Metals, this series of tests was run and this report written.

The work was suggested by Prof. J. O. Keller, head of the Industrial Engineering Department, Pennsylvania State College and a member of the above-mentioned committee, and supervised by him throughout. It was in the nature of a continuance of the work which he did at the plant of Pratt & Whitney during the summer of 1924, the results of which were published in the Mid-November, 1924, issue of MECHANICAL ENGINEERING under the title "A Comparison of the Herbert Pendulum Hardness Tester with Other Hardness Testers." Professor Keller found a close correlation between the Rockwell hardness tester, the Brinell method of hardness testing, and the Herbert pendulum time test. He also used the Herbert scale test and the work-hardening test, but found that they tested properties different from those dealt with by the other methods.

It was with the idea of ascertaining whether or not these or any other measurable properties bear any relation to the drawing properties of the metals, that the experiments about to be described were performed.

Many concerns engaged in pressed-metal work are using some form of hardness testing in an effort to predetermine the drawing properties of metal—or "drawability," as it will be designated hereafter in this paper; but for the most part the methods employed have been highly unsuccessful, causing an enormous waste of metals which failed in the forming or drawing process. It was that particular phase which was studied by the authors during their research, and their aim was to help somewhat in the large amount of research necessary before some infallible method is discovered for predetermining drawability.

There are a great number of conceptions of hardness, and these lead to confusion of terms. There is the Moh scale or scratch hardness, the scleroscope or elastic hardness, the Rockwell and Brinell or indentation hardness, the Herbert flow hardness, work hardness, and work hardening, machinability, plastic indentation, etc. However, it will be sufficient to find and measure that property or that properties which are factors of drawability, being careful not to confuse the terms used, and not to think of them as definitely related under the all-inclusive word "hardness."

The Boston Pressed Metal Company, being much interested in the tests proposed, offered marked samples of metals such as they might buy for drawing purposes, the drawing qualities of which were unknown by the college. These were to be tested by any of the available methods; and the opinions of the investigators as to their relative and absolute "drawability" were to be determined. The Boston Pressed Metal Company knew, by actual shop tests, those samples which could be drawn and those which could not, and thus it was possible to check the results of the research by a very practical method—the actual process for which the tests were conducted.

A series of scleroscope tests were conducted on each specimen; but since many of them were so thin as to be materially affected by the character of the anvil, no great value was attached to readings.

All Rockwell tests were performed with the $^1/_{16}$-in. steel ball and 100-kg. weight, so a good comparison of values was obtained. However, some of the sheets were too thin to be tested in this manner, since the depth of penetration approximated the thickness of the sheet, pressing the metal in the lower part of the impression against the anvil, and giving a reading composed of the resistance to indentation of the metal and of the hardened steel anvil. Since by Professor Keller's research the Rockwell and the Brinell methods checked so well, the Brinell numbers were computed from the Rockwell numbers by a table found in the handbook accompanying the Rockwell machine and reproduced here as Table 1.

TABLE 1 CONVERSION OF ROCKWELL B-SCALE HARDNESS NUMBERS TO BRINELL NUMBERS

Rockwell B-scale	80	75	70	65	60	55	50	45	40	35	30	25	20
Brinell numbers	151	138	126	117	108	101	95	88	83	79	74	70	67

There were no variations found due to the minute particles of carbon and to the variations in indentation hardness of various grains. Evidently the ball covers an area large enough to mechanically average these variations, which are inevitable, and to give uniform readings over the entire surface. This feature, in addition to its simplicity, makes the Rockwell machine a valuable one for those who desire to learn only the indentation hardness; but, according to pressed-metal manufacturers, this is not a solution of the problem of drawability. It indicated, for example, that specimens Nos. 4 and 5 will draw well, but according to the experience of the Boston Pressed Metal Company, they will not draw at all. Specimen No. 7 was shown to possess poor drawing qualities, but it really is one of the best of those examined.

In the use of the Herbert pendulum, the difficulties which have been mentioned by so many investigators were again experienced. It is very difficult to balance the pendulum, and even when this has been accomplished, for no apparent reason it will suddenly give erratic readings and be again out of balance. Then, too, the slightest air currents materially affect the readings; and it is necessary to perform the tests in a closed room, being careful not to allow the apparatus to be struck even by the current of air set up by natural breathing.

The ball upon which the pendulum moves is only 1 mm. in diameter, which is hardly large enough to cover an area on the specimen which will average the variations in the composition, size, and orientation of the individual grains. This statement is well borne out by photomicrographs of the ball impression in various metals taken by Mr. Herbert and Professor Keller. In the extreme case of two samples, the structure of which is shown later in this report, the ball would scarcely cover one grain and might easily be measuring the hardness of only one grain or of several grains in one of the infinite number of proportions possible.

It was also found that a slightly roughened surface had a marked effect upon the consistency of readings. Even the surfaces of some hot-worked metals were found so uneven that the ball was in a depression, on an elevation, or rolling up an incline. It was not possible to grind the surface for fear of changing the structure by heat-treating or work-hardening.

Because of these variations from the correct readings, all of the tests performed with the Herbert pendulum were repeated on each specimen from fifteen to thirty times in order to make certain of the accuracy of the data obtained.

For the time test the pendulum is adjusted so that its center of gravity is 0.1 mm. lower than the center of the supporting ball. The specimen is accurately leveled and the pendulum gently placed upon it. By means of a feather, the operator moves the pendulum so that the bubble travels over five or ten divisions of the scale. After ignoring the first few swings, the period of ten swings or five complete oscillations is timed with a stop watch, and the number of seconds required for these oscillations is called the "time hardness" number. As proved by Professor Keller and Mr. Herbert, there is a definite relation between this number and the Brinell number.

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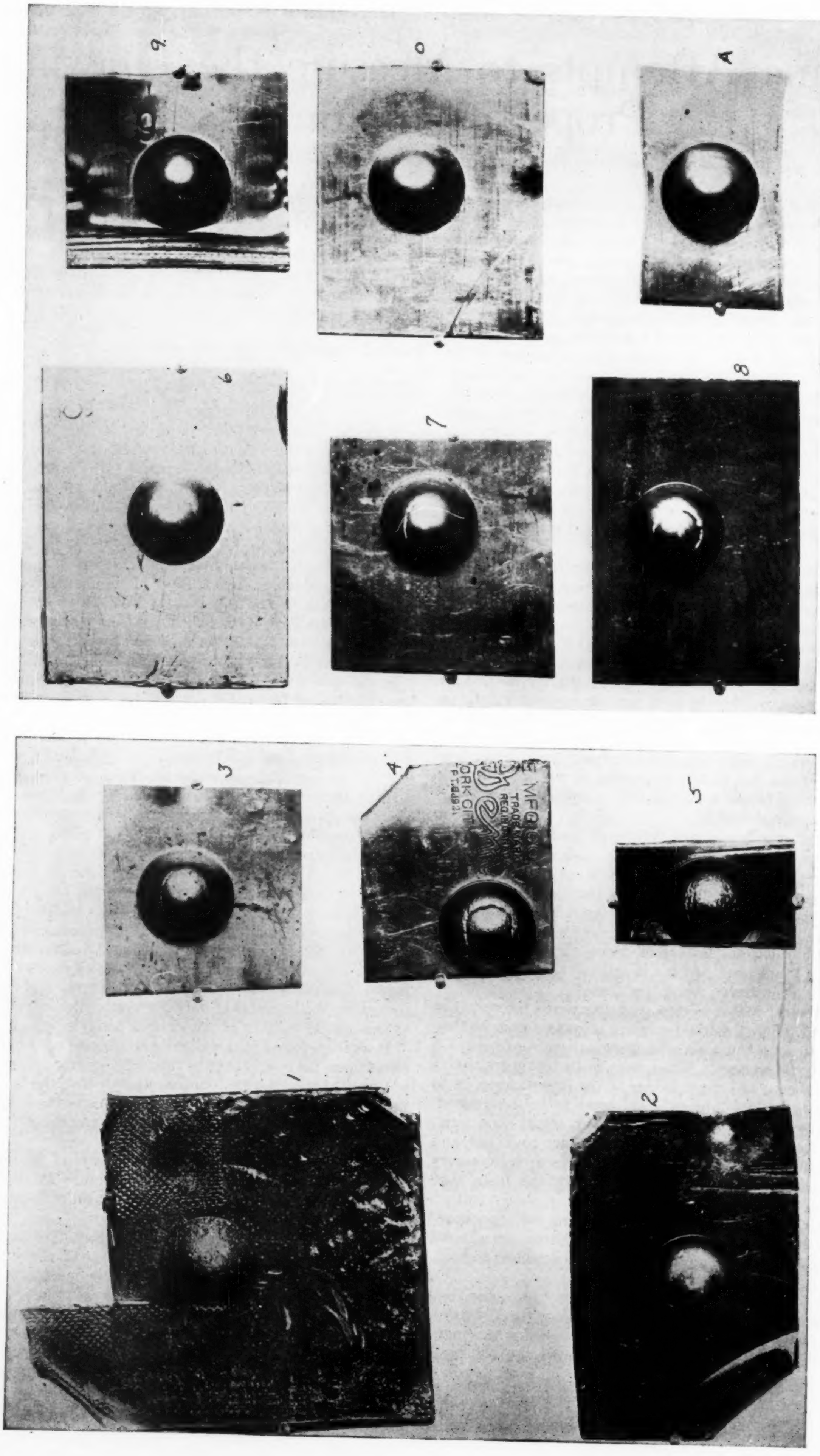


FIG. 1 ERICHSEN-MACHINE TESTS OF DRAWABILITY OF VARIOUS SPECIMENS OF SHEET METAL

This ratio, expressed by means of a formula, is

$$B = 10\ T\ (\text{when } T > 33^1/_3)$$
$$B = 0.3\ T^2\ (\text{when } T < 33^1/_3)$$

where B is the Brinell hardness number and T the time hardness number.

No particular difficulties, except those previously mentioned, were experienced in conducting this test; and in fact it is the easiest test performed with the pendulum. Since it measures the same kind of hardness as the Brinell method and the Rockwell method, and since it is much more difficult to operate than either of these, the pendulum is not valuable because of this test alone. One advantage, however, of the pendulum test over both the Brinell and the Rockwell is that on hard polished specimens the pendulum does not noticeably mar the surface.

The scale test may be performed in two ways giving materially different results but apparently measuring the same property of the metal. The original scale test is accomplished by setting the instrument on the specimen in the horizontal position and gently tilting it with the hand until the bubble comes to either 0 or 100, depending on whether it has been tilted clockwise or counterclockwise. It is then released; and the number of graduations which the bubble traverses during the first swing is the "scale hardness" number. Another method of conducting the test is to set the pendulum initially on the specimen so that the bubble is at 0 or 100, and then release it. This gives a scale hardness which does not include the work hardening caused by moving the pendulum so that the bubble travels from 50 to 0 or 100.

In both of these methods the personal element is a large factor in the reading obtained. It is very difficult to set and move the instrument in exactly the same way every time. That objection could be eliminated by the use of apparatus which would give a uniform setting; but the tests did not give an indication of drawability. They indicated, for example, that No. 4 would draw very well, but as a matter of fact it was one of the two poorest specimens for this work. Several of the other results were also very much in error as to the drawability.

The flow number, as described by Mr. Herbert, is obtained by dividing the "scale hardness" number by the "time hardness" number. This is admittedly rather a vague property and, for the authors' purpose, was found quite useless. Practically none of the indications were later found correct.

In the work-hardening test the pendulum is set on the specimen so that the bubble is at 0 or 100. It is allowed to swing, and the number of graduations passed over by the bubble is recorded. Just as the bubble stops moving the pendulum is grasped and is forced to continue its swing until the bubble is at the other end of the scale. It is then released and the reading taken. This is continued until the size of the numbers ceases to become larger with each successive swing. The numerical increase in hardness from the original value to the largest value obtained is prefixed with a letter indicating the number of the swing at which the largest reading was obtained. Most of our specimens gave the largest reading during the first swing after the original one. Hence the increase was prefixed with the letter "A."

The theory involved is that the ball mechanically works the metal, and while working it registers the increase in indentation hardness. This is a very logical procedure for determining drawability, since it seems highly probable that the fracture of metal during a drawing process is caused by the work-hardening capacity which hardens the metal to a brittleness. However logical it seems, the results obtained were quite different from the actual drawability. Nos. 4 and 5 were again placed as good drawing specimens and several of those with excellent drawing properties were classed as poor.

It may be that the error is caused by slippage of the ball in its indentation, for the authors are thoroughly convinced that this occurs. A more or less inaccurate proof follows.

Pendulum swings through approximately 27 deg.

Diameter of ball = 1.0 mm.

Circumference of ball = $\pi d = 1.0\pi = 3.1416$ mm.

Travel of ball in horizontal straight line, assuming pure rolling, $= T$

$$T : \text{circumference of ball} :: 27° : 360°$$

or

$$T = \frac{3.1416 \times 27}{360} = 0.2327 \text{ mm.}$$

Total length of impression = T + radius of ball in 0 position + radius of ball in 100 position
= $T + 2r$
= 0.2327 + 1 mm. = 1.2327 mm. or 1.233 mm.

The ratio of length of impression to its width cannot be less than 1.233 to 1.0 because the largest possible width is 1.0 mm. and the smallest possible length, if the ball does not slip, is 1.233 mm. Any variation from these extremes tends to decrease the ratio and make the contention that slippage does occur more apparent.

By actual measurements of a number of photomicrographs, the ratio of length to width was found to be about 1.94 to 1.0. Since the theoretical ratio cannot exceed 1.23 to 1.0, there is some distance there which can only be accounted for by admitting slippage. It will be noticed that those inaccurate measurements were taken in the direction which was most disadvantageous to the substantiation of the proof; and that the possible irregularity in the line of swing of the pendulum increases only the width and not the length as measured on the photomicrographs. Then if irregularity has occurred, it has increased the width and decreased the ratio and does not at all weaken the proof, crude as it may be.

The tests conducted on the Erichsen machine came nearer to answering the authors' question than those on any other testing machine.

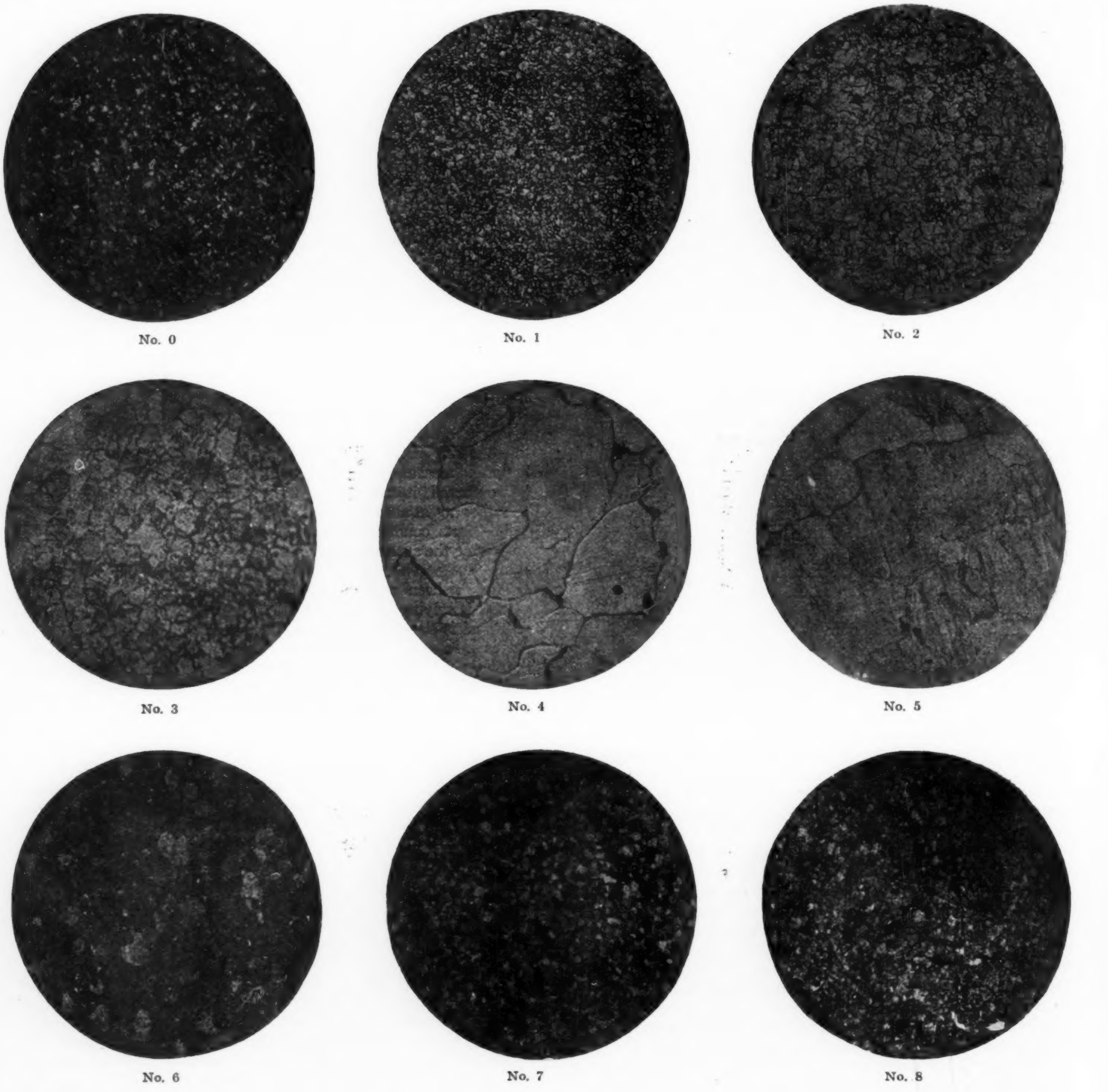
The Erichsen machine for testing metal sheets and strips has as its underlying principle the tensile test. The sheet or strip to be tested is clamped in the machine and its thickness is read. By means of a large handwheel, a smooth semicircular dome forces the sheet out through the die which holds it. The inventor stresses three points in connection with the test: (1) After the thickness has been measured, the handwheel is turned back 5 small divisions on the scale in order to give the test piece a certain amount of play. A clutch is now pushed in and, by turning the handwheel to the right, a bulging will be immediately noticed in the mirror. (2) Watch the image in the mirror carefully until the point of fracture is reached. The character of the dome of the specimen is very important. In general, a smooth dome indicates a sheet of good drawing qualities, while a rough dome indicates large grain size due to overannealing and a sheet of no drawing qualities at all. (3) The extent a sheet draws to fracture, plotted against its thickness, gives an "Erichsen value." Here the authors were momentarily brought to a halt, for, as far as they could ascertain, the inventor of the Erichsen machine had devised no way of comparing sheets of different thicknesses and different compositions.

Working along this line the authors developed a "drawability scale" in the following manner: A tangent was drawn to one of the Erichsen-machine curves for brass of excellent drawing qualities, and a perpendicular was erected to this tangent. From the points obtained by plotting thickness against draw to fracture, lines were drawn parallel to this perpendicular, and by actually scaling along this line the authors arrived at what might be called a percentage of drawability, calling the good brass points 100 per cent. This was at best a rather crude method, but further investigation in that direction should be of value to Erichsen-machine manufacturers and users, as the result obtained from one drawability scale checked fairly well with the report on drawing qualities sent to the authors later by the Boston Pressed Metal Company.

The Erichsen test failed mainly in not picking sheet No. 2 as one of excellent drawing qualities.

It did very well in picking Nos. 4 and 5 as sheets having no drawing qualities whatever (rough dome showed large grain size due to overannealing), and in picking No. 6 as a sheet of very poor drawing qualities.

Photomicrographs of metal in the hands of any person who understands them may be of infinite value to manufacturers of metal products. It has only been recently that photomicrographs have come to be widely used, and many of the older engineers know little or nothing about them. The authors feel confident, however, that their future is assured, for they proved to be a great aid to the



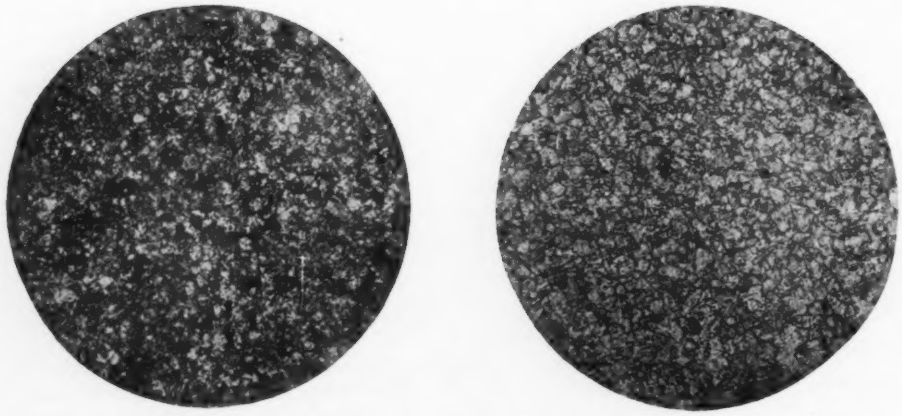


FIG. 2 PHOTOMICROGRAPHS OF SPECIMENS OF SHEET METAL TESTED FOR DRAWABILITY. MAGNIFICATION, × 70

(All specimens etched in a 4 per cent solution of nitric acid and alcohol.)

authors in helping them to form decisions which later were found to be correct.

The sheets on which the investigations were conducted (with the exception of No. 9 brass) were all very low-carbon steels. No. 7 was a little higher in carbon content than the other sheets.

Referring now to the photomicrographs, it may be easily seen that in some cases they alone indicate the drawing qualities of the sheet. For instance, Nos. 4 and 5 are eliminated at once as their extremely large grain size prohibits drawing. Any draw or bend of these two sheets, no matter how slight it may be, causes them to break along the grain boundaries and makes them valueless. Similarly, a careful inspection of Nos. 1, 2, 7, 8, and 10 shows them to be low-carbon steels with very small grain size, which is a necessary quality for a good draw. No. "A" shown in this connection is a low-carbon steel of excellent drawing qualities which the authors include in this report merely for purposes of comparison.

As regards Nos. 3 and 6, no definite decision could be made from the photomicrographs alone, but tying them in with the results obtained on the various testing machines, No. 3 was found to be fairly good and No. 6 very poor for drawing.

As a matter of fact, the authors feel that it would be rather dangerous to base a decision as to the qualities of a metal on a photomicrograph alone. Other qualities are continually entering in, and it would seem that the safest thing to do is to base the decision on the photomicrograph in connection with the reading of some testing machine, the type of machine depending upon the quality in the metal that it is desired to measure.

TABLE 2 DATA OBTAINED IN DRAWABILITY TESTS OF METAL SPECIMENS

Sample number	Scleroscope values	Rockwell	Herbert time test	Brinell numbers calculated from Herbert time test	Herbert scales	Herbert work hardness	Herbert flow numbers	Erichsen Values Thickness	Fracture	Scale value	Character of Erichsen dome
0	25	57.5	16	77	25	A10	1.34	0.775	9.0	0.62	Smooth
1	17	55	17.7	94	21	A39	1.38	Specimen too thick			
2	17	47.5	16.2	79	23	A34	0.915	3.04	9.3	0.42	Smooth
3	17.5	(a)	16.1	78	25	A18	1.38	0.54	8.3	0.67	Smooth
4	23	29	15.1	69	15	A6	1.45	1.43	10.2	0.62	Very rough
5	24	38	15.6	73	23	A9	1.50	1.50	9.85	0.58	Very rough
6	32	79	19.6	115	30	A33	1.26	1.49	8.4	0.48	Rough
7	27	64	17.2	89	21.5	A11.5	0.98	0.90	9.8	0.66	Very smooth
8	27	59	18.1	99	19.5	A11	0.925	1.39	10.85	0.69	Very smooth
9	12	(a)	13.0	51	12	A4.5	1.47	0.33	11.3	0.89	Very smooth

(a) Specimens too thin.

Table 3 gives the drawability scale as obtained from the best at the top to the poorest at the bottom. The lines drawn show how the various tests changed their placement in the cases of two of the specimens. Following the column giving the authors' conclusions are the determinations of drawability as found by practice in the plant of the Boston Pressed Metal Company. It is not to be assumed that the gradations are equal between the specimens as rated and that there is any way of telling how much the metals will draw, other than by describing them with such vague adjectives as "very good," "good," "poor," "very poor," etc. However, for the manufacturer this will be sufficient until a better method is found.

An endeavor to explain the various ways in which the authors arrived at their conclusions is now in order. In the case of sheet No. 1, great difficulties were experienced in obtaining accurate readings from both the pendulum and the Rockwell tester due to the rough, uneven surface of the specimen. It was too thick to test in the Erichsen machine without special dies, and consequently the authors' opinion was formed in this case mainly through a careful inspection of the photomicrograph, which they interpreted to show a low-carbon steel of very fine grain structure. They rated this sheet as one that would draw well.

With sheet No. 2 much the same difficulties were experienced as in the case of No. 1. However, the authors were able to perform an Erichsen test which gave a low Erichsen value. A photomicrograph showed the sheet to be a low-carbon steel with a fine grain structure. These two points combined with the fact that there is a striking resemblance between the photomicrographs of No. 2 and No. A led to the selection of No. 2 as a sheet that would draw well.

The pendulum and Rockwell machines gave No. 3 a rather central position between the two extremes 9 and 6. The Erichsen gave a high Erichsen value and supposedly indicated a sheet of excellent drawing qualities.

A study of the photomicrograph, however, led the authors to believe that while the sheet was a low-carbon steel, the grain size was a little large in comparison with the ones they had already picked as good drawing sheets. Sheet No. 3 was designated as one of fairly good drawing qualities.

Sheets Nos. 4 and 5 are so similar that they will be treated together. Here the pendulum and the Rockwell testers failed singularly in an effort to measure drawability, for both of them on all tests gave low readings which seemed to indicate sheets of excellent drawing qualities. The Erichsen machine performed excellently here, for the moment the sheet started to draw, the surface of the dome roughened. At the point of fracture (a low Erichsen value incidentally) the surface of the dome was very rough and it could be seen with the naked eye that the drawn part of the sheet had actually broken apart, along the grain boundaries. The absurdly large grain structure is also very well brought out by the photomicrograph.

Sheets Nos. 4 and 5 were designated as steel of no drawing qualities at all.

All the testing machines but the Erichsen gave sheet No. 6 the highest reading, meaning the poorest one for drawing purposes, and this is correct. A low "Erichsen value," a rough dome, and a peculiar photomicrograph showing a low-carbon steel of rather large, irregular grain structure led to the rating of No. 6 as a sheet of few or no drawing qualities.

TABLE 3 COMPARISON OF RESULTS OBTAINED BY VARIOUS TESTS

	Rockwell	Herbert time	Herbert scale	Herbert work hardness	Herbert flow	Erichsen	Authors' Conclusions	Report of Boston Pressed Metal Co.
Best	9	9	9	9	5	9	9	Brass, excellent
	4	4	4	4	9	8	1	H.R.S. excellent
	5	5	8	5	4	3	7	C.R.S. good
	2	0	1	0	3	7	8	H.R.S. excellent
	3	3	7	8	1	0	2	H.R.S. excellent
	1	2	2	7	0	4	0	C.R.S. excellent
	0	7	5	3	6	5	3	Sheet Steel, fair
	8	1	0	6	7	6	6	C.R.S. very poor
Poorest	7	8	3	2	8	2	4	Poorest
	6	6	6	1	2	1	5	Poorest

Due to a high Erichsen value and a photomicrograph showing a fine, even grain structure, the authors rated No. 7 as a sheet of excellent drawing qualities. In this decision they were slightly in error, for while the Boston Pressed Metal Company rate this steel as one of good drawing qualities, they point out the fact that there is danger of cracking in a long draw due to a slight excess in carbon content over the ordinary carbon content for good drawing sheets.

A high Erichsen value with a correspondingly good photomicrograph led to the rating of No. 8 as an excellent drawing sheet, despite the fact that the pendulum and Rockwell testers gave it high "hard" readings.

All the testing machines used combined in picking No. 9 as the best drawing sheet. This one gave a very low "work hardening" value on the pendulum, a low Rockwell reading, a high Erichsen value, and a very smooth Erichsen dome. This brass sheet was the best-drawing one of the lot.

No. 1 was also rated by the authors as a good drawing sheet. With it they found quite the same conditions existing as with Nos. 8 and 7. The pendulum and Rockwell tester gave it high, poor-draw readings, while the Erichsen-photomicrograph combination led them to designate it as a sheet of good drawing qualities.

It is the opinion of the authors that at present the best method of measuring the drawability and ductility of sheet metal is the Erichsen machine used in conjunction with photomicrographs.

The research just completed is only a very small portion of that necessary to a satisfactory solution of the problem of drawability.

The Erichsen machine came very close to providing a correct solution, and further investigation with it would probably be most valuable.

Since this machine seems to be based on the elongation phase of the tensile test, that test might well be given some attention. This may be elongation per unit length or elongation per unit length per unit of cross-sectional area. It will probably be necessary to change the standard testing machine so that it will read elongation as accurately as does the Erichsen.

Another series of tests might well be conducted on a machine conceived of by the authors, the basic principle of which is that metal, when deformed, tends to harden; and it is this hardening which presages failure.

An apparatus might be constructed by which a metal could be tested for indentation hardness, deformed by a certain number of length units in tension (or a certain number of degrees in bending), and then tested again for indentation hardness. The metal will have hardened considerably, and this may be expressed in absolute units or in a percentage of the original hardness; and the results may be found very valuable in determining drawability. The authors conducted a few very crude tests of this nature in connection with a Rockwell machine, and found that those metals which would not draw well hardened most rapidly; and so they are convinced that such a machine offers an attractive field for designers and research men.

In conclusion, the authors wish to thank the Pratt & Whitney Company for the use of their Herbert pendulum, and Herman A. Holz, Inc., for the use of the Erichsen sheet- and wire-testing machine. They are also indebted to the Boston Pressed Metal Company and to the late Douglas P. Cooke for supplying the samples upon which the tests were conducted, and for the interest shown by them in the investigation. Especially, however, is credit due to Prof. J. O. Keller, Head of the Industrial Engineering Department of the Pennsylvania State College, for suggesting the research and for his enthusiastic interest, without which the work described would not have been accomplished.

Testing Metals for Aircraft

THE standardization of physical tests used in predicting the characteristics metals will display in service offers many problems for investigation. Chief among these are selection of representative samples, the design of specimens and the methods of loading.

Strictly speaking, the test results obtained from a metal specimen represent only that particular piece at point of fracture. However, there are advantages to be gained by saving some stock for construction, which makes certain concessions necessary, and there our troubles begin.

The major responsibility for the selection of representative samples rests with the manufacturer in the use of uniform raw materials and maintaining uniform smelting and rolling practice. Unless the metals supplied are uniform within specified limits, no amount of physical testing short of a specimen from each bar will give representative results.

Even under the best mill control, there is considerable danger of impurity segregations and piping at the center of large bars, forgings, and sheets. This condition is more prevalent in aluminum alloys than in steel, which is partly due to the newness of the art. The location of specimens, then, with respect to the longitudinal axes of bars, forgings, and sheets from which they are taken, will vary with materials and sizes.

In general the results of physical tests are most affected by the geometric shape of the specimens used.

It is common practice to specify that tubing shall have certain tensile properties when tested in either full section or flat specimen. Ordinarily tubes which have a tensile strength within the capacity of the largest testing machine available are pulled in full section, while larger tubes are flattened and specimens prepared similar to those used for sheet metals.

Abrupt changes in contour of a stressed member introduce components with consequent resultant stresses of higher intensity than the loading would otherwise produce. The intensity of these resultant stresses is directly proportional to the abruptness of change in contour, whereas the area affected is greater for more gradual contour changes. Such a condition is found at the shoulder radius of the ordinary round and flat tensile specimens, and many failures that occur at this point can thus be accounted for. Because of the complexity of these stresses, they have almost completely eluded mathematical analyses, but by photoelastic methods they have been clearly isolated and measured.

For design information a figure is given in the original article showing approximately how these complex stresses occur in tensile specimens. It will be noted that the region of high stress extends into the parallel gage portion of the specimen and, if the true tensile properties of the material are to be determined, it is necessary that these abnormal stresses be eliminated from that section of the specimen shown as the gage length. This can be done by increasing the parallel length sufficiently to allow a gage length of material which will be subject only to pure tensile stresses. The amount by which the parallel length of the specimen must be increased is directly proportional to the shoulder radius, and for this reason it is desirable to keep the shoulder radius as small as practicable without incurring abnormal stresses of sufficient intensity to cause failure at that point.

Another factor which contributes to these abnormal stresses at the shoulder radius is the relative enlargement of the gripping end of the specimen. It has been found that failures near the shoulder are practically eliminated if the enlarged ends of specimen are not more than 13 per cent larger in diameter or width than the gage section. This simply reduces the abruptness of change in contour.

When preparations were being made for the construction of the American airship *Shenandoah* at the Naval Aircraft Factory, the question was raised as to the best type of tensile specimen to use for testing duralumin sheet metal. The results of this investigation are timely for showing some of the effects of variations in gage width, parallel length and gage width-thickness ratio. This investigation covered a range of gage widths from 0.185 in. to 1.250 in., sheet thicknesses from 0.015 in. to 0.250 in., and parallel lengths from 2.250 in. to 3.500 in., the gage length in all cases being 2 in. Space will not permit a report of the investigation.

So far as the writer is aware it has been generally believed that the more nearly a rectangular specimen approached a square cross-section, the greater would be the deformation under tensile loading.

The new tests clearly show that this is not the case.

It is evident that even slight variations in geometric shape of test specimens have effects that will be readily reflected in the test results, and that much care should be used in selecting standard test specimens for aircraft work, where specifications are necessarily very rigid.

Barba has pointed out that "Geometrically similar bodies of the same material, under identical conditions of stress, undergo similar deformation." The use of this fundamental law in the design of round tensile specimens is especially important. Since they have to be machined separately, they can be made geometrically similar and in various sizes without causing variations in test results. In the case of flat specimens, however, the solution is not so simple, as individual machining would entail prohibitive expense. The alternative here is so to design and standardize the specimen that the true properties of the material will be measured and then calibrate it for the various thicknesses of sheet and materials it may be called upon to represent.

The writer is conducting a series of tests on carbon steel, alloy steel, and duralumin tubing to determine the comparative results to be expected from use of flat and full-section tensile specimens, and if possible to establish a fundamental basis for their design.—N. S. Otey, Engineer of Tests Naval Aircraft Factory, Philadelphia, in *The Iron Age*, Dec. 17, 1925, p. 1660.

Power for Textile Mills

A Survey of the Possibilities of the Production of Power by Water and Steam and of the Purchase of Electric Current, with Conclusions as to the Plans to Be Followed for Various Types of Mills

By CHARLES T. MAIN,[1] BOSTON, MASS.

MOST of the earlier textile mills were located upon a river in order to take advantage of water power. Many of the manufacturing centers were started in this way, and the sites of many of the isolated mills were chosen for this reason. Many of the water powers which have been so used have been outgrown, and in some of these places there is a preponderance of steam power over water power. New centers of manufacturing have grown up where cheap fuel and low rates for transportation can be obtained, and many mills are now driven by steam power.

More recently the transmission of electrical current and the use of electrical power in the mills have caused water powers which were remote and of no value to become useful and valuable, and have enabled the construction of central power stations near the mines or on tide water where cheaper fuel can be obtained. These recent developments have made it possible to locate the mills more advantageously with reference to labor centers and with reference to the physical structures, light, and railroad facilities.

Cost of Manufacturing

The chief items of the cost of textile manufacturing are materials and labor. The cost of power is rarely over five per cent of the total cost of the product of the mill, and while this cost is an item which should receive careful consideration, it is of more importance to locate in some place where a sufficient number of operatives can be procured and where reasonable freight rates can be made, than to locate where power is cheap and the other items are lacking. The relative importance of locating where power is cheap increases as the ratio of the cost of power to the value or cost of the product increases.

Some of the earlier mills located on a variable stream, primarily for the sake of using water power, which power to a large extent requires supplementary steam power, are probably handicapped on account of their location and the restricted methods of construction, and by the necessity of maintaining and running a double power plant.

At the present time many of these restrictions have been removed on account of the possible use of electric power produced by the company itself, or which can be purchased from some power company producing by water or steam, or a combination of both.

In many instances the promoter of a new enterprise can choose between producing his own power and purchasing electric current from a public-service corporation. The latter course is now largely followed by mills of moderate size which have not a considerable use for steam or warm water in the manufacturing processes. The problem of the type of plant to be used has largely disappeared.

Electrical Installations

With the exception of some plants of small size, nearly all the power installations being made in textile mills now employ electric transmission. In this paper it is therefore assumed that the power will be transmitted electrically.

In the earlier electrical installations it was common practice to use large motors, 100 hp. or more in size, to drive large groups of textile machines. There has been a continuous tendency to decrease the size of the group of machines driven by one motor, and to use the individual motor for each machine. It is common practice now to limit the size of motors for group drives to about 40 or 50 hp., and to use individual motors ranging in size from $^1/_2$ hp. to about 10 hp. on many of the textile machines.

As regards the conditions which affect the power problem, textile mills may be divided into two general groups:

a Plain-goods cotton mills, which require little or no steam or warm water in their manufacturing processes, and other similar mills

b Woolen and worsted mills, which require large amounts of steam and warm water in their finishing processes, and so can make use of the waste heat from the generation of power, and similar mills.

There is, roughly, a million and a quarter horsepower used by the cotton mills and about a third of a million in the woolen and worsted mills in this country.

Steam Power

Nearly all values and costs of power are at the present time compared with the cost of producing power with steam. All of the statements of cost which follow are based on present prices, and are subject to change from time to time with the change in any element going to make up the totals. Prior to 1913 prices and costs were fairly constant; since 1913, however, they have increased so that today they are, roughly, double the 1913 prices.

An industry which is not yet established can, by using steam power, locate at any place where it seems desirable, but if possible the location should so be made as to warrant a supply of water for boilers and condensers and for manufacturing purposes, if any is required.

In making up the cost of steam power, all charges have been considered except interest and taxes on the cost of land. The fixed charges, including depreciation, interest, insurance, and taxes, have been assumed at 12.5 per cent, and the running time at 50 weeks of 48 hours each, or 2400 hours a year. In determining the cost per kilowatt-hour it has been assumed that the average load for the running time is 90 per cent of the capacity of the plant. The cost of coal is assumed at \$7 per long ton delivered in the coal pocket, and oil at \$2 a barrel in tankage.

The principal items affecting the cost of steam power are as follows:

1 Cost of fuel delivered to boilers
2 Amount of power produced
3 Fixed charges on cost of plant
4 Repairs and maintenance
5 Attendance and supplies
6 The net cost is reduced in some concerns where the waste heat of the power plant can be used in the manufacturing processes in the form of low-pressure steam or warm water.

Cost of Steam Power, Using Steam Turbines

In most textile mills the power plant will vary from 1000 to 5000 kw. capacity. There will be some instances where the power used is less than 1000 kw., and some in which the power required will be more than 5000 kw., but for the purposes of the present paper the author has considered this range as sufficient for illustration.

For most textile mills requiring plants of less than 5000 kw., the installation of two-story boiler houses, mechanical stokers, and mechanical coal-handling apparatus does not seem warranted to reduce the unit operating costs, which include fixed charges.

For a 5000-kw. plant, the last two columns of Table 1 show the

TABLE 1 COST OF STEAM POWER, USING STEAM TURBINES, IN TEXTILE-MILL PLANTS

(Operating 50 weeks of 48 hours each, or 2400 hours per year)

Size of plant in kw.	1000	2000	3000	4000	5000	5000
Boiler house: no. of stories	1	1	1	1	1	2
Type of stokers	hand	hand	hand	hand	hand	mech.
Coal-handling method	hand	hand	hand	hand	hand	mech.
Cost of plant per kw.	\$178	\$152	\$130	\$120	\$110	\$133
Coal used, lb. per kw-hr.	3.1	2.7	2.6	2.5	2.4	2.2
Power cost burning coal:						
Yearly cost per kw.	\$55.00	\$47.00	\$44.00	\$41.00	\$39.00	\$38.00
Cost per kw-hr. in cents.	2.56	2.18	2.04	1.90	1.81	1.79
Power cost burning oil:						
Yearly cost per kw.	\$58.00	\$48.50	\$45.00	\$42.00	\$39.00	\$43.00
Cost per kw-hr. in cents.	2.66	2.24	2.10	1.94	1.81	1.93

[1] Engineer. Past-President A.S.M.E.

Contributed by the Textile Division and presented at the Annual Meeting, New York, November 30 to December 4, 1925, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. All papers are subject to revision.

differences in costs between a simple installation and the more complicated plant. With modern plants the figures given in the table for cost of installation and operation are fair, when steam is not used for anything but power.

In many places mills run more than 48 hours a week, coal can be delivered at $4 a ton, and construction costs are less.

With 54 hours a week, $4 coal, and no change in cost of plant, a 1000-kw. plant could operate at $47.44 a kilowatt, or 1.95 cents a kilowatt-hour, all costs included, and a 5000-kw. one could operate at $33.40 a kilowatt, or 1.37 cents a kilowatt-hour, all costs included.

Effect of Use of Waste Products

It has been common practice for many years to use the exhaust steam of non-condensing engines and steam from the receivers of compound engines for manufacturing purposes and for heating buildings.

The saving by the use of exhaust steam, which would otherwise go to waste, is considerable. In some mills, especially colored mills, if the power is not produced by steam, so that the low-pressure steam can be used for manufacturing purposes, it will be necessary to maintain a boiler plant of sufficient size to produce an equivalent amount of exhaust or receiver steam thus used.

The bleeder type of steam turbine lends itself to this manner of running better than the reciprocating steam engine, and supplies steam free from oil for process work.

In addition to a saving in coal, there is some saving in fixed charges on a portion of the boiler plant, and in attendance in the boiler house.

The reduction effected by the use of low-pressure steam upon the net cost is shown approximately in Table 2.

TABLE 2 REDUCTION IN COST OF POWER EFFECTED BY THE USE OF EXHAUST OR BLEEDER STEAM

(Cost of coal assumed at $7 per long ton)

Low-pressure steam in per cent of total	25	50	75	100
Savings in power cost:				
Yearly savings per kw	$7.00–$10.00	$12.50–$13.50	$18.00–$23.50	$23.50–$30.50
Savings per kw-hr. in cents	0.33–0.45	0.58–0.63	0.85–1.10	1.08–1.42

Water Power

The cost, and consequently the value, of water power depends upon a variety of factors, but the essential fact is whether, considering the combined result of all these factors, power can be produced and delivered as cheaply in this manner as by any other method.

The chief items affecting the cost and value of water power are as follows:

1 The quantity of water and the uniformity of flow during the year or a succession of years.

2 A power whose flow is constant is the most valuable.

If the flow is variable, it must be supplemented by steam or other power, and the value diminishes as the need of supplementary power increases. The variability may be so excessive as to make the cost of maintaining and running a double plant more expensive than it would be to produce the same amount of power by steam power alone.

The power which can be derived from a definite quantity of water increases directly in proportion to the head, and the cost of development increases per horsepower as the head diminishes.

3 The location of the power has a large effect upon the value, but as stated before, the ability to transmit power electrically has rendered useful and of value many powers which otherwise would be valueless. It is now possible in many cases to so locate a mill as to get the desirable features and to run it electrically by water power, but even in such a case the location of the water power has a large effect upon its value, for the cost of transmission lines will be greater for longer distances to be run and the line losses greater.

4 The use of exhaust steam and overflow water from the condenser for manufacturing purposes tends to reduce the net cost of steam power, and therefore to reduce the value of water power for this particular use.

The chief items in the yearly cost of power are:

1 Fixed charges, as interest, depreciation, insurance, and taxes on the development
2 Repairs and maintenance
3 The cost of supplementary power, if any is necessary to make up for the fluctuation in water power
4 Attendance and supplies.

Cost of Hydroelectric Power

No definite sum can be fixed on as the cost of water power, as this depends largely upon the conditions which affect the cost of the development. Each case must be considered on its own merits. As the chief cost of water power is usually the fixed charges on the cost of the development, the first cost is the most important item for consideration.

In a development substantially made, the fixed charges for interest, depreciation, insurance, and taxes and the repairs may be as low as 9 per cent with a short transmission line to 12 per cent with a long line. For the purposes of this paper they are assumed at 10 per cent.

One hundred dollars a kilowatt would be considered a low-cost development. The cost in most instances would be greater than this, and some developments have been made in which the cost has been so great that it has been impossible to make it a paying investment until the capital charges were scaled down.

A uniform power development at reasonable cost is a valuable asset which bids fair to increase in value as time goes on. A uniform power at high cost may not be profitable. A varying power at high cost is pretty sure not to be profitable.

Table 3 shows in a general way the cost of power under varying conditions of construction cost. These costs are for current on the switchboard in the generating station. The effect of transmission losses is to increase the cost of power delivered to the mill in proportion to the percentage of loss on the transmission lines. These losses for short lines would be roughly 5 per cent, and for long lines, 10 per cent.

TABLE 3 APPROXIMATE COST OF UNIFORM HYDROELECTRIC POWER DELIVERED AT POWER-PLANT SWITCHBOARD

Size of plant in kw	1000	2000	3000	4000	5000
Assumed plant cost per kw	$100.00	$100.00	$100.00	$100.00	$100.00
Yearly power cost per kw	14.00	13.25	12.50	11.75	11.00
Cost per kw-hr. in cents	0.65	0.61	0.57	0.53	0.50
Assumed plant cost per kw	$200.00	$200.00	$200.00	$200.00	$200.00
Yearly power cost per kw	25.00	24.35	23.45	22.60	21.75
Cost per kw-hr. in cents	1.17	1.13	1.09	1.05	1.00
Assumed plant cost per kw	$300.00	$300.00	$300.00	$300.00	$300.00
Yearly power cost per kw	36.20	35.30	34.40	33.55	32.65
Cost per kw-hr. in cents	1.70	1.65	1.60	1.55	1.50

Adding 10 per cent to the last set of figures in Table 3, we have, as shown in Table 4, the approximate cost at the end of the line, assuming the cost of plant and line at $300 a kilowatt.

TABLE 4 APPROXIMATE COST OF UNIFORM HYDROELECTRIC POWER DELIVERED AT CONSUMER'S END OF TRANSMISSION

Size of plant in kw	1000	2000	3000	4000	5000
Yearly power cost per kw	$39.80	$38.80	$37.80	$36.90	$35.90
Cost per kw-hr. in cents	1.87	1.82	1.76	1.71	1.65

Effect of Variable Power

That portion of the power which is uniform and which can be depended upon all of the time is called "permanent power" or "primary power," and that power which is variable and cannot be furnished all the time is called "surplus power" or "secondary power." It is the latter kind of power that will now be discussed.

Variable power necessitates a supplementary plant of sufficient capacity to make up the deficiency of water power, or the purchase of electric current for this purpose.

In some few instances the variation of flow is so great that the extreme low flow is insufficient to generate any useful power, and sometimes the backwater may be so great as to reduce the working head to such an extent as to make it useless for power. In such cases as these it would be necessary to maintain a supplementary plant of the same capacity as the primary plant, costing, roughly, three-quarters as much per kilowatt as given for regular steam power—for the purpose of discussion, say, $100 a kilowatt.

Usually there is some permanent useful power in all developments, but all power developed above the permanent must be supplemented, as stated above, if it is desired to produce continuous power, and there are very few industries which can succeed unless they can be run continuously.

The fixed charges on the supplementary plant would go on, whether this plant were used or not, at 12.5 per cent or $12.50 per kilowatt-year. To this must be added the cost of operating, which under a varying load would be less economical than regular steam power, and would cost from $2.30 to $3.25 per kilowatt a month.

The total cost of power in such cases would be approximately as shown in Table 5.

TABLE 5 APPROXIMATE COST OF VARIABLE HYDROELECTRIC POWER

Power Costs per Kilowatt per Year for Hydroelectric Plants having Steam Auxiliary Power Plants

Size of plant in kw.	1000	2000	3000	4000	5000
Cost of hydroelectric plant per kw.	$200	$200	$200	$200	$200
Yearly power cost, hydroelectric plant, per kw.	$25.00	$24.35	$23.45	$22.50	$21.75
Auxiliary Steam Plant:					
Yearly fixed charges per kw.	12.50	12.50	12.50	12.50	12.50
Operating cost each month per kw.	3.25	2.75	2.50	2.40	2.30
Total Yearly Power Cost per Kw.:					
Steam plant running 1 month	40.75	39.60	38.45	37.50	36.55
Steam plant running 5 months	53.75	50.60	48.45	47.00	45.75

Every $100 increase in the cost of the hydroelectric development adds $10 a year in fixed charges to the cost of power per kilowatt.

Thus a 1000-kw. plant costing $200 a kilowatt costs $25 a kilowatt for steady power. If supplemented by steam to its full capacity for five months, the total cost of power would be $53.75. If the cost is $300 per kw. including transmission, the yearly cost if supplemented full for five months would be $65.00 ÷ 0.90 = about $72 delivered.

In order to determine whether a water power should be developed and the extent to which it should be developed, a comparison of the total cost of producing the amount of power required by the water power supplemented, if necessary, by steam power or purchased electric current, should be made with the cost of producing the same amount of power by steam alone or purchasing all of it.

The cost of the water power and the supplementary power must not be more than the cost of steam power alone or purchased current alone.

If considerable quantities of steam or warm water can be used in the manufacturing processes, the amount which can be invested in water power is less than it could be for a plain mill.

As the variations in costs and uses are great, each case requires careful study, and there must be kept in mind, as far as can be foreseen, possible future changes in fuel prices and advance in the art.

Purchased Power

Many mills now have the opportunity of purchasing electric current from some central power station or power company which is producing power either by steam or water power, or both.

There are many points of advantage to the mill if such power can be purchased at a reasonable price, which, however, will not be discussed here.

Assuming that the mill will consider the purchase of power on a basis of cost of production by its own plant, how much can it afford to pay for the same?

Table 6 gives approximate fair prices that plain- and colored-goods textile mills could afford to pay for guaranteed power.

TABLE 6 FAIR PRICES FOR PURCHASED POWER FOR PLAIN- AND COLORED-GOODS TEXTILE MILLS

Capacity of plant kw.	Running 48 hr. per week, coal at $7 per ton — Cost per kw-year	Running 48 hr. per week, coal at $7 per ton — Cost per kw-hr.	Running 54 hr. per week, coal at $4 per ton. — Cost per kw-year	Running 54 hr. per week, coal at $4 per ton. — Cost per kw-hr.
Plain Cotton Mills using exhaust steam for heating and slashing only:				
1000 kw.	$55.00	2.56 cents	$47.50	1.95 cents
5000 kw.	$39.00	1.81 cents	$33.50	1.37 cents
Colored-Goods Mills using about 75 per cent of the power-plant waste heat:				
1000 kw.	$32.00	1.47 cents	$28.50	1.17 cents
5000 kw.	$21.00	0.96 cent	$19.00	0.78 cent

With an established mill with a good power plant all built, the mill has its investment in steam plant to charge off and it could afford to pay an amount somewhat less than if it were a new mill and could save the investment in steam plant.

The amount to charge off will depend on how many years the existing plant would naturally run in an efficient manner, and it can be spread over this length of time or done in a shorter period.

If the steam plant is not efficient, no such deduction should be made.

For amounts of power less than 1000 kw., the price which could be paid would increase.

All of the figures presented have been made for textile mills in which the load is fairly uniform and the service less severe than for almost any other business. Some other kinds of business can pay considerably more for power than textile mills.

General Conclusions

Having made a survey of the possibilities of the production of power by water and steam, or the purchase of electric current, a conclusion can be reached as to what plan should be followed. Each problem requires its own solution.

At the present stage of the art, the following general statements can be made fairly safely.

For Existing Mills:

1 *Plain Mills Owning and Operating Water-Power Developments of Some Merit, Usually in Connection with Steam Power:*

a If the water-power plant is old and inefficient, remodel it and thus increase its output.

b If the steam-power plant is old and inefficient, and electric current can be purchased at a reasonable rate, purchase current sufficient to make up for the lack of power from the water-power plant.

2 *Plain Mills Run by Steam Power Alone:*

If the steam plant is old and inefficient, and electric current can be purchased at a reasonable rate, it should be done.

3 *Colored Mills:*

a If the water-power plant is old and inefficient, a study should be made to ascertain if it will pay to remodel it, and to make still further use of the water for power. In some cases, where the mill has grown, it has been necessary to conserve all the water for manufacturing purposes.

b There is usually so much use for low-pressure steam and warm water for process work that all or nearly all of the heat rejected from the steam engine or turbine can be used, thus reducing the net cost of power to an amount probably so low that it will not pay to purchase electric current.

For New Mills:

a Plain mills of moderate size can probably purchase current cheaper than it can be generated by an isolated plant at the mills.

b Colored mills of any size can usually produce power and steam and warm water for manufacturing processes cheaper than they can purchase electric current and produce the required amount of steam and warm water.

Discussion

IN THE oral discussion following the presentation of the paper, C. H. Bigelow[2] said that he had known of cases in which simple changes in the management or operating force in the power plant had reduced the cost nearly 33 per cent with very little change in the equipment of the plant. The operation in the plant itself had a good deal to do with the figures given by the author. Incidentally, his company had brought their cost per kw. down to about $1^3/_4$ cents.

A. W. Benoit,[3] who presented the paper in the author's absence, replying to questions propounded by W. B. Cooper,[4] said that in a textile plant the turbines were ordinarily set for escape at about 15 lb. and process steam actually used at about 10 lb.; he had two or three dyehouses running down as low as 5 lb., which gave very satisfactory results. Ordinarily, however, 10 lb. was aimed at.

Very few textile plants could use all the exhaust steam that their total power requirements would make, and except in very rare instances non-condensing turbines were not used. The only exceptions were large converting plants where there were numerous

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[3] Special Assistant, Charles T. Main, Boston, Mass. Mem. A.S.M.E.

[4] Richmond, Va. Mem. A.S.M.E

dyeing and finishing processes and all the exhaust steam could be used. The average textile plant began to use as much exhaust steam as it made only at the peak period, and almost invariably used the bleeder type of turbine, taking what exhaust steam was needed as the requirements came along, and turning the rest of it over to the condenser. That portion, however, was not lost because the condenser then became a heater, and the water was suitable for pumping into the storage tank and could be used again, thereby further cutting down the power cost. He had in mind two or three installations where the amount of heat that was wasted in the river was exceedingly small. The cost of power was hardly anything beyond maintenance and fixed charges on the plant, plus, of course, a small amount of heat also in the unit.

Sidney B. Paine[5] gave it as his opinion that a textile manufacturer would better invest his money in looms and spinning frames than in a power plant. On a new mill he would get 25 per cent on his money, and on a power plant he would simply get back his interest and taxes, which he charged to his customers. Mr. Paine was very willing to recommend that a mill of any size today should purchase its power provided it could do so at a proper price, and especially if the power was reliable, for it was necessary to have uniformity of speed and voltage.

In selecting motors for individual drive, Mr. Paine stated that it was highly important that a large enough size should be purchased to meet the maximum demand that might ever be imposed on the loom.

Geo. H. Perkins,[6] who presided over the session, referring to the use of purchased power by mills, called attention to statistics given in the Progress Report of the Textile Division[7] which showed that the percentage of purchased power to the total primary power used by textile mills as reported in the 1919 census was 27 per cent, or nearly 100 per cent more than in 1914.

He spoke briefly regarding the work of the Textile Division and of the plans under way for participation in the regional meeting of the Society to be held in Providence the first week in May.

With reference to a practice that is becoming quite common, namely, tying the mill prime mover into public-service circuits, Miles Sampson[8] said that his company had an arrangement of that nature which had operated quite well. His company had supplied the central station with some 3000 to 4000 kw. It had a large demand for process steam and could operate the arrangement profitably.

Mr. Benoit spoke of a small plant in which there was a 500-kw. turbine running condensing, but with extraction features, and from which the exhaust steam was taken and used for process work. All the steam not so used went to the condenser, and the water wanted for process work was thus obtained at 120 deg. and was put into storage tanks. In addition the plant was phased in with the public service, which served as a standby. The plant ran at noon, but shut the turbine down because the load was light and let the public-service company carry it. At night, when there was plenty of water, they gave the power to the public-service company. It was a small plant, but it had everything in it that would contribute to the success of such an arrangement, and when it balanced bills with the public-service company there was rarely anything to pay the latter.

Charts for Studying the Oil Film in Bearings

By GEORGE B. KARELITZ, EAST PITTSBURGH, PA.[1]

It has been shown several times that the hydrodynamical theory of lubrication satisfactorily explains the mechanism of lubrication. Since the necessary calculations are very complicated, the practical application of the theory, up to the present time, has been very difficult. The charts presented in the paper give the designer or investigator a means of determining with sufficient accuracy the shape and pressures in the oil film for bearings under different conditions.

BEARINGS generally used at present for high-speed machines are of the central partial type, the arc of bearing varying in different constructions from 90 to 150 deg. A sufficient oil supply is provided for the building up of a "perfect" oil film, and for this case the mechanism of lubrication has been analyzed by several authors and shown to follow the hydrodynamical laws of flow of viscous fluids.

A cross-section of a bearing is shown in Fig. 1; the arc of bearing AB is central, so that $BF = FA$.

The general equation of the motion of oil in the case of a very long bearing surface where side leakage was neglected was given by N. Petroff[2] and O. Reynolds,[3] and is

$$\frac{dp}{dx} = -6\mu U \frac{h - h_1}{h^3} \qquad [1]$$

where p = oil pressure in the film
x is measured along the circumference of the shaft
μ = absolute viscosity of the oil
U = rubbing velocity of the shaft
h = variable thickness of the oil film
h_1 = thickness of the oil film at the point of maximum pressure.

To form an approximate picture of the pressure distribution in an oil film of a bearing, the following suppositions are made.

(*a*) The forces acting on the journal are the pressure of the oil acting normally to the shaft surface, and the friction force. Their resultant must be equal to the load on the bearing. The friction force being comparatively small, the load is taken as equal to the resultant of the forces due to oil pressure alone.

(*b*) The oil pressure in the annular clearance outside the carrying arc AB is taken as $p = 0$, as it is small, only a few pounds per square inch in a properly designed bearing, and may be neglected in comparison with the pressures existing in the carrying oil film. The vacuum which theoretically ought to be created under the bearing cover cannot exist due to oil vapor being formed in the clearance. As to the wedge sections NB and NA, the angle t in Fig. 1 is large enough (above 2 deg.) for the pressure built up in the wedges to be considered as negligible. The pressure of the oil being $p = 0$ at A, grows to some maximum at a certain point with the corresponding thickness of film h_1 and falls down to the point C of nearest approach between journal and bearing. The pressure p at C is considered equal to zero (the pressure from C to B theoretically is negative).

(*c*) The experiments of Kingsbury, Lasche, and others have shown that the actual distribution of pressures in the oil film along the bearing axis follows very nearly a sine curve or a parabola. The assumption is made that in the middle plane of a bearing the pressure is the same as in a very long bearing (infinite length), the pressures in the oil uniformly decreasing to the ends following one of the above-mentioned laws. It is evident that the carrying capacity of a bearing is only a part of what it would be with ends closed and pressures along the length uniformly equal to those in the middle plane. In the case of a sine law the carrying capacity is

$$s = 2/\pi = 0.637$$

[5] Manager Textile Division, General Electric Co., Boston, Mass. Mem. A.S.M.E.
[6] Consulting Engineer, Boston, Mass. Mem. A.S.M.E.
[7] MECHANICAL ENGINEERING, December, 1925, p. 1139.
[8] Textile Engineer, American Printing Co., Fall River, Mass. Mem. A.S.M.E.

[1] Westinghouse Research Laboratory.
[2] N. Petroff. New Theory of Friction. German edition by Wurzel, Hamburg, 1887.
[3] O. Reynolds. On Theory of Lubrication. Phil. Trans., Roy. Soc. of London, 1886.

Contributed by the Special Research Committee on Lubrication and presented at the Annual Meeting, New York, November 30 to December 4, 1925, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. Abridged. For discussion see p. 132.

and in the case of a parabolic law it is

$$s = {}^2/_3 = 0.667$$

of what it would be with closed bearing ends. In the following calculations the value $s = {}^2/_3$ will be taken. The coefficient s may be called the "longitudinal efficiency" of the bearing.

(*d*) The bearing shell is considered as absolutely rigid, and the axis of the shaft as parallel to the axis of the bearing (no misalignment of shaft and bearing). It has to be borne in mind that the distortion of the bearing may affect considerably the distribution of pressures and the friction losses.

(*e*) In the case of a bearing being furnished with an annular leak-off groove or two grooves at the ends, the pressure in the grooves is to be taken as $p = 0$, the active length of the bearing being the length between the groove and the opposite end of bearing or the length between grooves.

The basic equation [1] gives the pressures in the middle plane of a bearing. As

$$x = r\theta$$

where r is the radius of the journal, and θ is measured in radians,

$$dx = rd\theta$$

and

$$\frac{dp}{dx} = \frac{1}{r} \times \frac{dp}{d\theta}$$

Taking $\theta = 0$ at the point C of nearest approach, the radius of the bearing being $r + \delta = r + mr = r(1 + m)$, or the radial clearance being $\delta = mr$(m is from 0.001 to 0.002), the eccentricity of the journal in the bearing being $a = c \times \delta = c \times m \times r$, with $0<c<1$, the variable clearance h is

$$h = \delta - a \cos\theta = \delta(1 - c\cos\theta) = mr(1 - c\cos\theta) \ldots. [2]$$

The smallest clearance is at $\theta = 0$. $h_{\min} = \delta - a = r \times m(1-c)$. Substituting [2] in [1], we have

$$\frac{dp}{dx} = \frac{dp}{rd\theta} = -6\mu U\frac{mr(1 - c\cos\theta) - h_1}{m^3r^3(1 - c\cos\theta)^3} \ldots\ldots. [3]$$

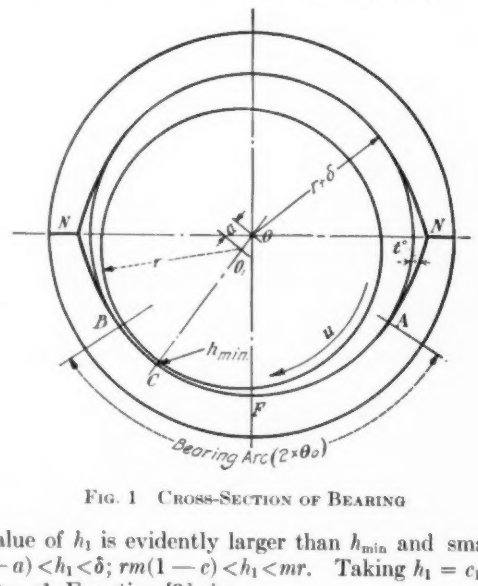


FIG. 1 CROSS-SECTION OF BEARING

The value of h_1 is evidently larger than $h_{\min}$ and smaller than δ, or $(\delta - a) < h_1 < \delta$; $rm(1 - c) < h_1 < mr$. Taking $h_1 = c_1mr$, where $(1 - c) < c_1 < 1$, Equation [3] gives

$$\frac{dp}{rd\theta} = -6\mu U\frac{mr(1 - c\cos\theta) - c_1mr}{m^3r^3(1 - c\cos\theta)^3}$$

$$= \frac{-6\mu U}{m^2r^2}\frac{(1 - c\cos\theta) - c_1}{(1 - c\cos\theta)^3},$$

or

$$\frac{dp}{d\theta} = -\frac{6\mu U}{m^2r}\frac{(1 - c\cos\theta) - c_1}{(1 - c\cos\theta)^3} = -\frac{6\mu\omega}{m^2}\frac{(1 - c\cos\theta) - c_1}{(1 - c\cos\theta)^3} \quad [4]$$

where

$$\omega = U/r = \text{angular velocity of the shaft}$$

The exact solution of Equation [4] is

$$-\frac{m^2}{6\mu\omega}p = \frac{2c(1-c^2) - 3cc_1}{2(1-c^2)^2}\frac{\sin\theta}{(1 - c\cos\theta)} - \frac{cc_1}{2(1-c^2)}\frac{\sin\theta}{(1 - c\cos\theta)^2}$$
$$+ \frac{(2 - c_1)(1 - c^2) - 3c_1}{(1 - c^2)^2\sqrt{1 - c^2}}\tan^{-1}\left(\sqrt{\frac{1+c}{1-c}}\tan\theta/2\right)$$

if $p = 0$ at $\theta = 0$. The evaluation of the numerical values of p is too complicated, and graphical integration is more practical.

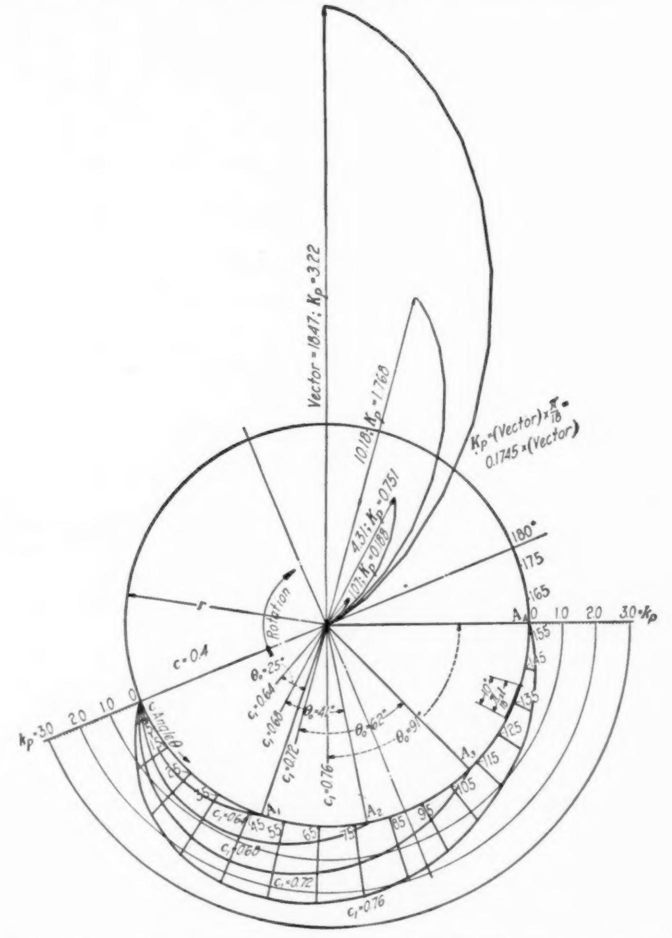


FIG. 2 CURVES OF PRESSURES EXISTING IN A BEARING FOR $c = 0.4$ AND VARIOUS VALUES OF c_1
(See Table 1.)

The values of the absolute viscosity μ, of the angular velocity ω, and of the bearing clearance m being given, the pressures in the oil film depend on the values of c and c_1, as shown by Equation [4]. Integrating,

$$p = -\frac{6\mu\omega}{m^2} \times \int\frac{1 - c\cos\theta) - c_1}{(1 - c\cos\theta)^3}d\theta$$

$$= -\frac{6\mu\omega}{m^2}\left\{\int\frac{d\theta}{(1 - c\cos\theta)^2} - c_1\int\frac{d\theta}{(1 - c\cos\theta)^3}\right\}$$

$$= k_p \times \frac{\mu\omega}{m^2} \ldots\ldots. [5]$$

where

$$k_p = -6\left\{\int\frac{d\theta}{(1 - c\cos\theta)^2} - c_1\int\frac{d\theta}{(1 - c\cos\theta)^3}\right\}$$

$$= p \times \frac{m^2}{\mu\omega} \ldots\ldots. [6]$$

Tables have been computed[4] giving the values of k_p for $c = 0.1$, $0.2, \ldots 0.8$ and certain values of c_1. The integration was made by summation of ordinates, the increment of θ being taken as 10 deg. Each value of c and c_1 represents a certain possible partial bearing, as shown for the case of $c = 0.4$ in Fig. 2. The point C is the point of nearest approach as in Fig. 1; the pressures corresponding to $c_1 = 0.64$; $c_1 = 0.68$; $c_1 = 0.72$ and $c_1 = 0.76$, as given

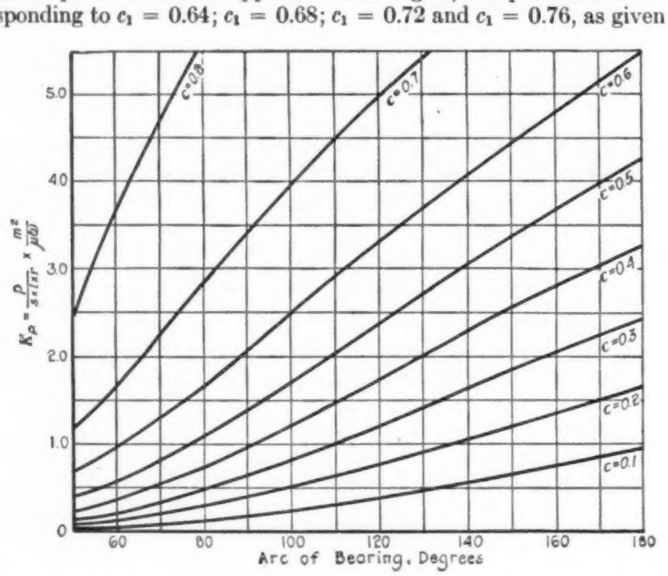


FIG. 3 RELATION BETWEEN ARC OF BEARING AND K_p FOR VARIOUS VALUES OF c

in Table 1, are shown by curves CA_1, CA_2, CA_3 and CA_4 correspondingly.

If a strip of bearing of one unit of length be taken, the pressure p is equal to the force applied to the journal surface per unit length

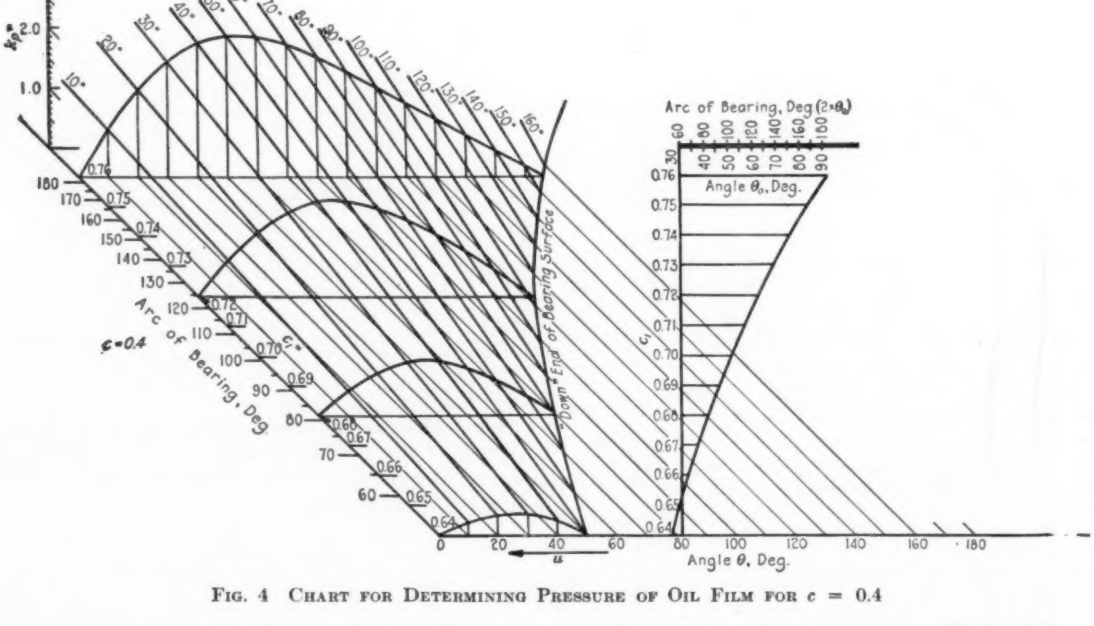


FIG. 4 CHART FOR DETERMINING PRESSURE OF OIL FILM FOR $c = 0.4$

of circumference. In Fig. 2 these forces are combined vectorially and the resultants are found. The carrying capacity of the bearing per unit length is then

$$K_p \times r \times \frac{\mu\omega}{m^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots [7]$$

where K_p is the load characteristic of the bearing strip and is found as shown in Fig. 2. The total load on the bearing being P, the active length of the bearing being l, and the longitudinal effi-

[4] These tables, similar to Table 1, are given in the unabridged paper.

TABLE 1 VALUES OF k_p FOR $c = 0.4$ (SEE FIG. 2)

$$k_p = p + \frac{\mu\omega}{m^2}$$

θ deg.	$c_1 = 0.64$	$c_1 = 0.68$	$c_1 = 0.72$	$c_1 = 0.76$
5	0.098	0.194	0.292	0.389
15	0.258	0.543	0.829	1.114
25	0.327	0.785	1.243	1.701
35	0.277	0.884	1.493	2.106
45	0.108	0.842	1.576	2.310
55	−0.155	0.681	1.517	2.354
65		0.436	1.354	2.273
75		0.138	1.121	2.107
85		−0.187	0.848	1.882
95			0.554	1.631
105			0.256	1.368
115			−0.042	1.098
125				0.831
135				0.569
145				0.313
155				0.062
165				−0.188

ciency of the bearing being s, the carrying capacity of the middle element of it has to be

$$1/s \times P/l = P/sl$$

and

$$K_p \times r \times \frac{\mu\omega}{m^2} = P/sl$$

or

$$P = K_p + \frac{r\mu\omega}{m^2} \times s \times l \quad \ldots\ldots \quad \ldots\ldots [8]$$

or

$$K_p = \frac{P}{slr} \times \frac{m^2}{\mu\omega}$$

The directions of the resultant vectors give the angles θ_0. The points A_1, A_2, A_3 represent the corresponding "down" ends of the active bearing surface, and the bearing being a central partial one, the resultant force has to be collinear with the bearing load, i.e., in the central plane; hence the angles θ_0 (Fig. 2) are equal to one-half of the bearing arc AB. It is evident that two fixed values of c and c_1 represent a certain possible central partial bearing of definite carrying capacity K_p and bearing arc $2 \times \theta_0$.

Diagrams similar to Fig. 2 were drawn for each value of $c = 0.1$ to $c = 0.8$ and subsequent graphical interpolation has given charts similar to Fig. 4 for studying the oil film in a bearing.[5]

The value of c corresponding to a given bearing arc and load characteristic K_p, is given in Fig. 3. The smallest thickness of the oil film is then found as

$$h_{\min} = mr(1 - c)$$

[5] These charts are reproduced in the unabridged paper.

It has to be noted that the value μ to be used for determination of K_p is the viscosity of oil in the oil film proper. It may be found approximately by taking into consideration that the average temperature of the oil film is from 5 to 10 deg. cent. higher than the temperature of the outflowing oil. The value of the viscosity is to be converted into units corresponding to the remainder of the data, the conversion coefficients being

$$1 \text{ poise} = 1.02 \times 10^{-6} \text{ kg-sec. per sq. cm.}$$
$$= 1.45 \times 10^{-5} \text{ lb-sec. per sq. in.}$$

Using the chart corresponding to the determined value of c or interpolating between two corresponding charts, the pressure curve for the oil film is plotted for the given bearing arc. The point of nearest approach is given by the length of the active oil film.

The use of the charts is seen from the following example. O. Lasche in his experiments[6] of 1918 used a bearing with the following elements:

$$\begin{aligned} \text{Diameter} &= d = 20 \text{ cm.} = 7.87 \text{ in.} \\ \text{Radius} &= r = 10 \text{ cm.} = 3.94 \text{ in.} \\ \text{Active length} &= l = 40 \text{ cm.} = 15.75 \text{ in.} \\ \text{Clearance} &= 0.34 \text{ mm., or } m = 0.014 \text{ in.} \end{aligned}$$

The rubbing speed at one series of tests was 30 meters per sec. or

$$U = 3000 \text{ cm. per sec.} = 98.4 \text{ ft. per sec.}$$

$$\begin{matrix}\text{Loads on} \\ \text{bearing}\end{matrix} = P = \begin{cases} a & 5200 \text{ kg.} = 11460 \text{ lb.} \ (92.3 \text{ lb. per sq. in.}) \\ b & 16000 \text{ kg.} = 36300 \text{ lb.} \ (284 \text{ lb. per sq. in.}) \end{cases}$$

The bearing arc was 150 deg. No data on the oil are given. Assuming the oil to be equivalent to "heavy turbine oil," the viscosities were approximately:

Case	Temperature	Assumed viscosity
a	57 deg. cent.	0.146 poise = 0.149×10^{-6} kg-sec. per sq. cm.
b	66 deg. cent.	0.121 poise = 0.123×10^{-6} kg-sec. per sq. cm.

Taking the longitudinal efficiency as $s = {}^2/_3$, the load characteristic K_p (Equation [8]) in Case a is

$$K_p = 1.26$$

From Fig. 3 for a bearing arc of 150 deg. and $K_p = 1.26$, c is found to be 0.21. From charts similar to Fig. 4 ($c = 0.2$ and $c = 0.3$) the pressure curves are plotted for the bearing arc of 150 deg. and by interpolation the curve $c = 0.21$ is found.

In Case b the load characteristic is

$$K_p = 4.66$$

From Fig. 3 for the bearing arc of 150 deg. and $K_p = 4.66$ the value of c is found to be 0.615. From charts similar to Fig. 4 ($c = 0.6$ and $c = 0.7$) the pressure curves for the bearing arc of 150 deg. are

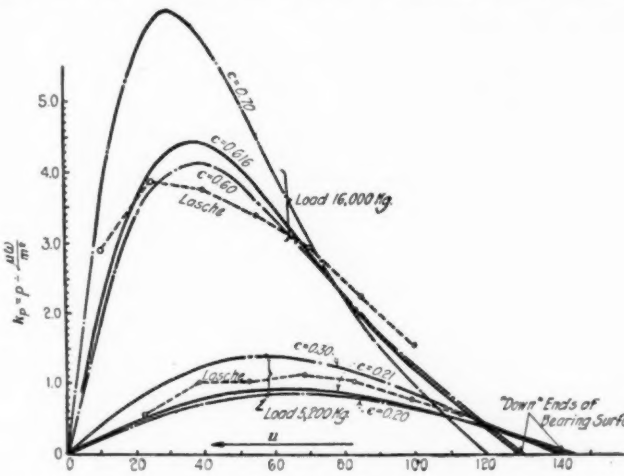


FIG. 5 COMPARISON OF PRESSURE CURVES AS DETERMINED FROM CHARTS AND AS FOUND IN LASCHE'S EXPERIMENTS

plotted (Fig. 5) and the curve for $c = 0.615$ is found by interpolation.

Lasche gives the observed pressure curves for Cases a and b. The pressures were converted into corresponding values of k_p by Equation [6] and plotted for comparison in Fig. 5. The coincidence of the curves can be considered as sufficient to justify the use of the charts for analyzing the behavior of a given bearing as to oil pressures and oil-film thickness. It can also be seen that the longitudinal efficiency is somewhat higher than ${}^2/_3$ in Case b and lower in Case a. This is to be expected since the oil-film thickness in Case b ($h_{min} = 0.0025$ in.) is considerably less than in Case a ($h_{min} = 0.0054$ in.).

[6] O. Lasche. Konstruktion und Material im Bau von Dampfturbinen und Turbodynamos, Berlin, 1920.

A Graphical Study of Journal Lubrication—III[1]

BY H. A. S. HOWARTH,[2] PHILADELPHIA, PA.

This paper continues the investigation of journal lubrication reported to the Society under the same title in 1923 and 1924. Friction curves are presented for central and offset partial bearings whose curvature radius exceeds that of the journal. The characteristics of fitted partial bearings are then studied, including their carrying capacities and friction.

THE investigation described in this series of papers was undertaken to determine *quantitatively* the relation between load, speed, clearance, viscosity, minimum film thickness, and friction in *common forms* of journal bearings. The character of the pressure curves and the shapes of the lubricating films were also determined so that the lubrication of a journal bearing could be readily visualized.

The two-dimensional mathematical treatment was chosen because of its simplicity. It neglects side leakage, assuming there is none, and it also assumes that the oil viscosity is constant from one end of the film to the other. The influence of friction upon the direction of the line of action of the resultant pressure has been neglected because of its relative insignificance. These assumptions lead to conclusions that are quite satisfactory for comparing one bearing form with another.

The results of this investigation have been represented by curves on charts of convenient form for ready reference. Suitable constants can be obtained from reliable experimental results, to correct these charts into close agreement with actual bearing conditions. The author has made no attempt as yet to check his analytical results against experimental ones. Great care must be used in selecting experimental results for this purpose because of the well-known tendency of investigators to neglect to observe (or publish) one or more important factors. These charts should guide experimenters, showing what data are necessary for completeness.

The author believes that the most useful features of his charts are those showing the *film thickness* and the *friction*, and how they vary with load, speed, viscosity, and bearing form.

The forms of bearings covered by this graphical analysis are: (1) full bearings; (2) partial bearings, subdivided into—(a) central, (b) offset, (c) fitted.

The characteristics of these four bearing series will be readily understood if a similar problem is solved on each of the correspond-

[1] Part I was presented in December, 1923, and published in vol. 45 of the Transactions, p. 421. Part I contains Figs. 1 to 19, inclusive, and Equations [1] to [12]. Part II was presented in December, 1924, and appears in vol. 46 of the Transactions, p. 809. Part II contains Figs. 20 to 34, inclusive, and Equations [13] and [14].

[2] General Manager, Chief Engineer, Kingsbury Machine Works. Mem. A.S.M.E.

Contributed by the Special Research Committee on Lubrication and presented at the Annual Meeting, New York, November 30 to December 4, 1925, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. Short summary. For discussion see p. 132.

ing charts. Assume a 2-in. journal carrying 120 lb. per inch of width (axial) at 300 r.p.m., on oil having an absolute viscosity 3.4×10^{-6} inches-pounds-seconds. The unit pressure w will be 60 lb. per sq. in. on the diametral section. Find the *minimum film thickness* and the *coefficient of friction* for a *full*, a 120-deg. *central*, and a 120-deg. *offset* bearing, each with a running radial clearance of 0.002 in. Find same also for a 120-deg. *fitted* bearing. The solution of this problem will be found in Examples 3, 4, and 5 in Part II, and Example 8 in Part III. These results are tabulated below.

Bearing	Minimum film thickness	Coefficient of friction
Full bearing	0.00153	0.00325
120-deg. central	0.000716	0.0022
120-deg. offset	0.000735	0.0019
120-deg. fitted	0.000582	0.0017

Thus by comparing these bearings it is found that the *journal friction* coefficient is lowest for the fitted, next for the offset, higher for the central, but highest of all for the full bearing. The distance of closest approach does not quite correspond, being least for the fitted, next for the central, greater for the offset, and greatest of all for the full bearing.

The study of partial bearings has now proceeded far enough to answer intelligently an important question that occasionally arises

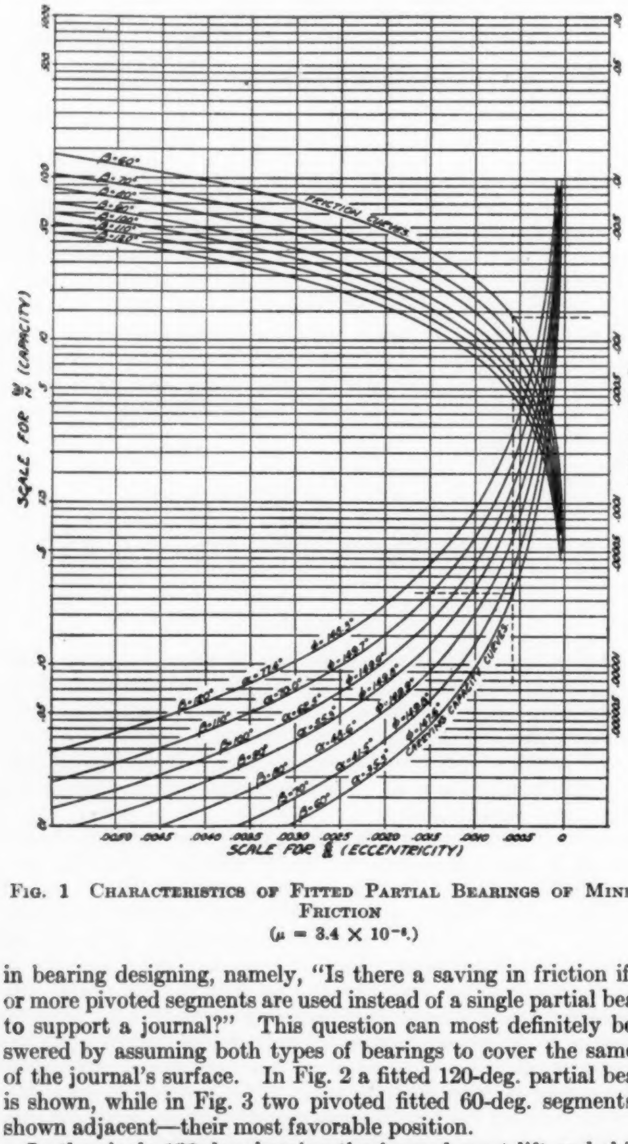
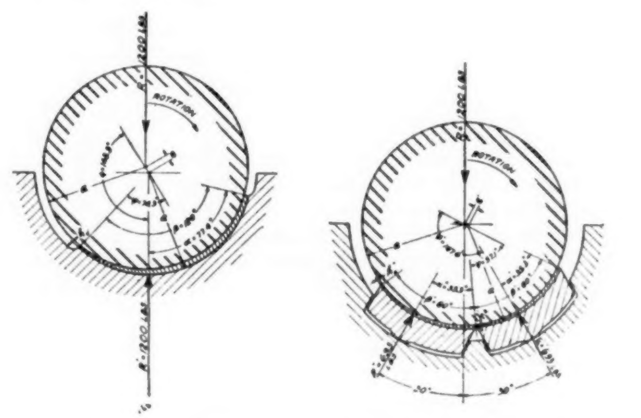


Fig. 1 Characteristics of Fitted Partial Bearings of Minimum Friction
($\mu = 3.4 \times 10^{-6}$.)

in bearing designing, namely, "Is there a saving in friction if two or more pivoted segments are used instead of a single partial bearing to support a journal?" This question can most definitely be answered by assuming both types of bearings to cover the same arc of the journal's surface. In Fig. 2 a fitted 120-deg. partial bearing is shown, while in Fig. 3 two pivoted fitted 60-deg. segments are shown adjacent—their most favorable position.

In the single 120-deg. bearing the journal must lift and shift to the left so as to form the wedge-shaped film. The eccentricity, the distance of closest approach, and the frictional coefficient can be determined by referring to Fig. 1.

In the double segmental bearing the journal must lift and the segments must tip to form the wedge-shaped films. Similar data can be obtained for this bearing also from Fig. 1. Example 9 (in the full text) shows the single bearing to be much superior to the double pivoted segmental bearing. More than two segments would be inferior to two.



Figs. 2 and 3 Comparison of 120-Deg. Fitted Partial Bearing and the Equivalent Double Pivoted Segment Bearing

Discussion of Papers on Lubrication

Mr. HOWARTH'S paper, forming the third part of his Graphical Study of Journal Lubrication, was the first of the two papers presented to be read and discussed. Three written discussions were presented, respectively, by G. B. Karelitz,[1] Robert C. H. Heck,[2] and H. T. Newbigin.[3]

Mr. Karelitz, while characterizing the paper as very valuable and giving for the first time numerical values of the friction in bearings, found that certain points ought to be taken into consideration. For example, in a short bearing the end leakage of the oil would cause considerable departure from the conditions of a long bearing dealt with in the paper.

Furthermore, as the question of oil flow in and through the bearing was of great importance, investigators should, according to Mr. Karelitz, exert their efforts along this direction, which so far had hardly been explored.

Professor Heck, referring to the mathematical treatment of the problem, thought that within the restrictions imposed, a simpler presentation might be made, this having the advantage that by adopting a physical rather than a mathematical reasoning, the limitations of its applicability would become much more clearly evident.

Although, due to some uncertainty in the fundamental theory and the neglect of end leakage, it could only serve as a guiding approximation, the paper came much nearer in making the film theory a basis of design than any previous effort along similar lines.

Mr. Newbigin also found that the omission of end leakage was regrettable, as with the reduction of length, in modern journal bearing design, this factor became increasingly important.

The saving in length was usually the deciding factor, of particular importance in the case of large bearings, and might be brought about without increasing the maximum unit pressure.

In the present paper the two-dimensional mathematical treatment had been adopted because of its greater simplicity, but Mr. Newbigin pointed out that Michell's mathematical study, "The Lubrication of Plane Surfaces," had enabled the problem to be solved for three dimensions. It applied equally to journal as to thrust bearings, and several hundreds of the former bearings fitted with pivoted pads were justifying this method of construction.

The chairman, Mr. Flowers, had ascertained from the author that this paper completed the series of analytical studies along the original plan, and raised the question whether the Society's Publication Committee should not be approached with the suggestion to put together in a reprint the group of papers, which had been distributed over several years, so as to make them available for consultation as a whole.

[1] Westinghouse Elec. Mfg. Co., East Pittsburgh, Pa.
[2] Prof. M.E., Rutgers College, New Brunswick, N. J. Mem. A.S.M.E.
[3] Michell Bearings, Ltd., Newcastle-on-Tyne, England.

F. O. Hoagland[4] stated that he believed that 75 per cent of the breakdowns in machine tools were due to lack of lubrication and that he wanted to emphasize the importance of the subject and the advantage it would be to all to have these various papers combined in one publication. He suggested that Mr. Bierbaum's paper on a similar subject, published a few years ago, should also be included in the group.

C. H. Bromley[5] thought that it would be useful to incorporate also a bibliography of the subject as related to the research side.

A resolution of thanks for Mr. Howarth's paper was adopted.

The second paper read was by George B. Karelitz—"Charts for Studying the Oil Film in Bearings." No written discussions were presented.

From the floor M. D. Hersey[6] asked if the comparison with Lasche's experiments was intended as an evidence in favor of the fact of a two-thirds longitudinal efficiency. To this Mr. Karelitz answered that he had shown two-thirds only as a matter of approximation, that it might be 70 or 60 per cent according to conditions.

H. A. S. Howarth stated that this factor would have to be determined by experiments, comparing the curves presented and the results of practice, to which Mr. Karelitz fully agreed, adding that the trouble was that the experiments were expensive and difficult to make.

J. M. Lessells[7] pointed out the discrepancies which exist between the results of Professor Moore's experiments on breaking down the pressure of the oil film and other papers dealing with the subject. Mr. Karelitz had stated that from recent experiments we could tell now positively that this question of oil rupture came to the question of mean permissible oil-film thickness, which it would be important to fix experimentally for all possible conditions of a journal in a bearing, because we could not allow any metal contact, no matter whether it was due to the rough surface of the material or to the misalignment between the journal and the bearing.

Radiation in Boiler Furnaces

BY B. N. BROIDO,[1] NEW YORK, N. Y.

There is now a noticeable tendency toward an extensive application of water-cooled furnace walls for absorbing heat by radiation. An analysis of the fundamentals of radiation and of the effect of water-cooled walls on the gas temperatures in the furnace is given in this paper.

There is a certain relation between the amount of fuel burned, the surface exposed to direct radiation in the furnace, and the total heat absorbed by this surface. Curves are given showing this relation for different installations and a standard curve is drawn which enables the designer to determine with sufficient accuracy for practical purposes what part of the total heat generated in the furnace at different ratings is absorbed by the water-cooled walls. This curve can also be used to find the heat transmission by radiation per square foot of heating surface for any given condition of the furnace.

The amount of radiant-heat-absorbing surface that can be installed advantageously in a furnace depends upon the type of furnace and the kind of fuel burned. Based on a number of installations with water-cooled walls, the most advantageous arrangement of radiant-heat-absorbing surface for given conditions is suggested.

The effect of radiation from gases on heat transmission, particularly with high temperature differences, and the influence of radiation upon the measurement of gas temperature, are briefly discussed.

THE rapid development of the steam turbine and the possibility of concentrating many power generators in large power stations have created the demand for steam in increased quantities. The logical progress has been, therefore, towards larger furnaces, larger boilers, and higher evaporation per square foot of boiler heating surface. With larger boilers and correspondingly larger furnaces, the maintenance of furnace walls becomes quite a problem, as the firebrick wall will not stand the high temperatures which occur when a boiler is operated at high efficiency. It would be necessary to admit excess air through the fire to reduce the furnace temperature to a degree that the walls would stand. This difficulty has been overcome, at least partially, by using hollow air-cooled bricks and, more recently, by using water-cooled walls.

Attempts have been made previously to water-cool the furnace walls of water-tube boilers, but no serious consideration was given to them until some of the boilers in the Hell Gate Station of the United Electric Light and Power Company of New York were equipped with so-called fin walls. These installations have proved conclusively that not only was the maintenance of the furnace decreased but the capacity of the boilers was appreciably increased. The water-cooled side walls of the Hell Gate boilers not only replaced practically all the brickwork in the side walls, but afforded considerable protection to the front and rear walls by absorbing the heat which they reflected and lowering the temperature of the furnace. In view of these results there is now a noticeable tendency towards a more extensive application of water-cooled walls.

This development has caused more thought to be given to the law of heat radiation than ever before. Tubes placed in a furnace absorb heat from the gases before they reach the boiler tubes, and this reduces the temperature in the furnace. The water-cooled walls generate a considerable amount of steam, making it possible to reduce the heating surface of the boiler proper for the same total evaporation. With a moderate amount of cooling surface in the furnace, it is possible to burn the fuel with a higher percentage of CO_2 and a correspondingly higher efficiency without the ill effect on the brickwork which is usually encountered with CO_2 contents and high furnace temperatures when water-cooled walls are not used. If the temperature of the furnace is lowered considerably, difficulty may be experienced in getting complete combustion with some kinds of fuel. The temperature of the gases in the furnace or passing through the boiler has considerable effect upon the superheater, which depends upon the heat absorbed from the furnace gases.

It is evident, therefore, that all designers of furnaces, boilers, and superheaters should know (1) what quantity of water can be evaporated by a given area of radiant-heat-absorbing surface, (2) what will be the influence of this surface on furnace temperature and combustion of the fuel, and (3) what amount of heating surface can be placed in a furnace to give the best results under given conditions. A discussion of these problems is the object of this paper.

RADIATION AND THE RADIATION COEFFICIENT

Of the three well-known methods by which heat may be transmitted, viz., by radiation, by conduction, and by convection, the last two occur within a body or a combination of bodies in such a way that the heat of these bodies is transmitted from one point to another by means of the particles of the body or through the body itself.

Heat transmission by radiation, however, occurs only from surface to surface. The heat travels from one body, or from one particle of the body, to another without giving up any heat to the air, gas, or any other matter that may fill the space between the two bodies or two particles of the body.

It is comparatively easy to prove that heat radiation has no effect upon the air contained between the body which radiates heat and the one which absorbs it. If one stands at some distance from

[4] Saco-Lowell Shops, Boston, Mass. Mem. A.S.M.E.

[5] Mgr., S. F. Bowser & Co., Ft. Wayne, Ind. Assoc-Mem. A.S.M.E.

[6] Physicist, U. S. Bureau of Mines, Pittsburgh, Pa. Mem. A.S.M.E.

[1] Consulting Engineer, The Superheater Company. Mem. A.S.M.E.

Contributed by the Power Division and presented at the Annual Meeting, New York, November 30 to December 4, 1925, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. Abridged.

[7] Engineer, Research Dept., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa. Mem. A.S.M.E.

a furnace provided with an easily opened door, when this door is quickly opened he feels the heat at practically the same instant he sees the fire, although the air between cannot by any means become so quickly heated. This shows that the heat passes through the air without heating it.

It is extremely difficult to determine by test the amount of heat radiated or absorbed. The difficulty exists mainly because it is very hard to separate the heat absorbed by radiation from that absorbed by convection, as these usually take place together.

For the last few decades the practical engineering world has accepted the formula established by Stefan in accordance with which the radiation emanating from a body is proportional to the fourth power of the absolute temperature. Boltzmann later proved this formula theoretically correct for the case of black-body radiation.

For practical purposes, the Stefan-Boltzmann formula is sufficiently correct for non-transparent bodies. It includes a coefficient which depends upon the material and the condition of the surface. It is questionable, however, whether this formula applies also to radiation from gases. It may be of interest to know how the coefficients for different materials were found.

The standard Stefan-Boltzmann formula for radiation is

$$Q = Cf\left[\left(\frac{T_1}{1000}\right)^4 - \left(\frac{T_2}{1000}\right)^4\right]$$

It shows that if a small surface f at the absolute temperature T_1 is completely surrounded by another surface at an absolute temperature T_2 so that all the heat radiated from f is absorbed by this surface, the amount of heat in B.t.u. that will be absorbed

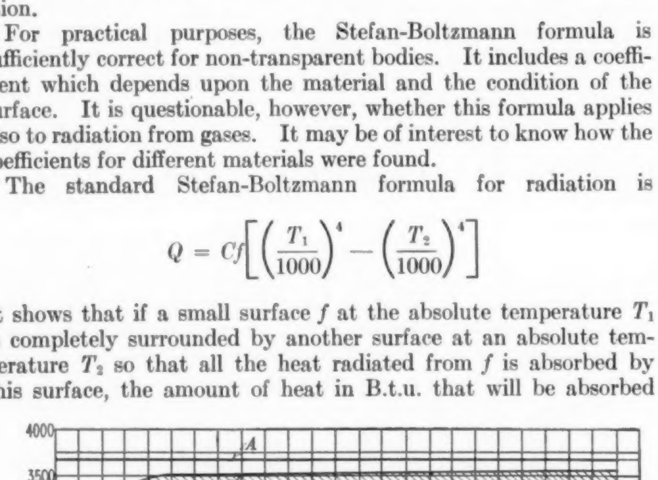


FIG. 1 COMPARISON OF ACTUAL AND THEORETICAL FLAME TEMPERATURES AT DIFFERENT COAL RATES

per sq. ft. per hr. will be Q, provided that the radiation coefficient is C. The coefficient of radiation was found to be as follows:

For candle soot	1543
For unpolished brass	357
For roughly polished copper	276
For oxidized steel	1530
For highly polished steel	462
For rough or highly oxidized cast iron	1557
For brick	1494

The principal problem is to determine the amount of heat which is radiated from one surface to another surface of a given size and at a certain position relative to the first.

In this case the general form of the Stefan-Boltzmann formula is

$$Q = CF\phi\left[\left(\frac{T_1}{1000}\right)^4 - \left(\frac{T_2}{1000}\right)^4\right]$$

where ϕ represents the distances and relative positions of the surfaces.

HEAT ABSORPTION BY RADIATION

The heat absorbed by radiation per square foot of surface depends upon the amount of fuel burned and the amount of heating surface that is located in the furnace, both of which influence the temperature of the flame or gases in the furnace.

Fig. 1 shows how the temperature of the flame varies with the amount of coal burned, also the influence of water-cooled walls upon this temperature. It is based on a furnace 18 ft. long, 18 ft. high, and 24 ft. wide, fired with coal having a calorific value of about 14,000 B.t.u. per lb., burned with 14 per cent of CO_2. The first two lower rows of the boiler present about 700 sq. ft. of surface, absorbing heat by radiation, and there is also heat-absorbing surface of about 1000 sq. ft. in the water-cooled walls and bottom.

Curve A represents the calculated furnace temperature which would result from combustion with the above coal without any losses. Curve B represents the actual average temperatures in the furnace under the above conditions with different rates of fuel consumption. Curve C shows what the temperature would be if no water-cooled radiation surface were present to absorb it. The shaded portion between curves B and C represents the temperature drop in the furnace due to heat absorption by radiation. Curve B approaches curve C as the rate of combustion of fuel increases, which shows that the heat absorbed by radiation does not increase in the same proportion as the fuel burned.

Probably due to difficulties of the analytic methods, many engineers have endeavored to find a practical relation between the amount of fuel burned, the surface exposed to direct radiation in the furnace, and the heat transfer per hour per square foot of this surface. In discussing the paper by Wohlenberg, Geo. A. Orrok mentions an empirical formula which was established as far back as the end of the last century. Since the introduction of water-cooled walls this problem has awakened renewed interest, and is the subject of study by those interested in furnace design.

The most important factor in connection with heat radiation is the relation between the total heat generated in the furnace and that absorbed by radiation; in other words, the fraction of generated or liberated energy which is absorbed in the furnace. Wohlenberg calls this the furnace absorption efficiency, and designates it by the symbol μ_4. The author endeavored to figure out this relation for a few cases, either directly where the amount of steam generated by the radiant-heat-absorbing surfaces was known, or indirectly by comparison with similar cases where no radiation occurred. There seems to be a certain relation between the value of μ_4 and the ratio between the total heat generated in the furnace and the amount of surface exposed to direct radiation. In Fig. 2 curves are plotted giving μ_4 for different cases. The ordinates show the ratio between the total heat liberated and the surface exposed to radiation, while the abscissas show the values of coefficient μ_4. Curve A is based on the tests with water-cooled walls in one of the original installations at the Cahokia station where there are 1800-hp. boilers, fired with pulverized fuel, and having vertical water tubes in the rear wall. Curve B is based on tests at Sherman Creek with a 600-hp. Springfield boiler, fired with pulverized fuel, and provided with two fin-type water-cooled walls at the sides and a radiant-type superheater at the rear wall. Curve C shows tests made by Weber in Vienna on a water-tube boiler fired with coal on hand-fired grates.

While there is no means of figuring out the amount of heat absorbed by the water-cooled walls in the Hell Gate Station, the author endeavored to determine this by working back from the coal burned and the temperature of the exit gases. In this way was determined the heat which would be absorbed in this boiler by convection alone. The remainder was then accepted as being absorbed by radiation, from which μ_4 was determined. The results are plotted as curve D.

Curve E is based on tests by W. F. M. Goss with a Jacobs-Shupert locomotive boiler at Coatesville, Pa., between 1911 and 1912. The values of μ_4 presented by curve F are taken from Wohlenberg's paper.

It is interesting to note that for a certain ratio between the total steam liberated and the amount of surface exposed to radiation, the variation of μ_4 for the six cases mentioned is less than 20 per cent, which would indicate that the average value of μ_4 as presented by curve G is sufficiently accurate for practical purposes to be used as a standard on which to base calculations. By means of this standard curve, one can determine what part of the total heat generated will be absorbed by the radiating surface in the

furnace for a certain rating of the boiler. This can be found by determining the ratio between the total heat to be absorbed at that rating and the total amount of radiating surface. The total heat should be multiplied by the factor μ_4 corresponding to the determined ratio, which gives the total heat absorbed by radiation. This curve can also be used to find the heat transmission by radiation per square foot of heating surface for any given condition of the furnace. Determine the total amount absorbed by radiation as before, and divide it by the number of square feet of surface exposed to radiation.

Very often the question arises as to how much steam will be evaporated by the water-cooled surface located in the furnace, that is, the water walls and bottom screen. That this problem can be easily solved by the use of the standard curve G of Fig. 2 is evident.

By the total heat-absorbing surface mentioned above is meant the projected surface exposed to the furnace, including the surface of the lower rows of tubes of the boiler section, the side walls of the furnace, and its bottom. As the lower rows of boiler tubes, the lower sides of which are exposed to radiation, are always covered by water, they present an excellent heat-absorbing surface. It has been suggested, therefore, when figuring the total radiant surface, to add 40 per cent of the lower tube surface or multiply the tube surface by 1.4. More correct results are also obtained if the projected surface of the bottom screen tube is multiplied by 0.75 to take care of the fact that this surface is mostly covered by ashes which reduce its heat-absorbing capacity.

Table 1 shows the heat transfer per square foot of projected area of the side wall of a standard water-tube boiler of about 1600 hp. for different percentages of radiant surface and amounts of coal burned.

TABLE 1 B.T.U. TRANSFER PER SQ. FT. OF PROJECTED AREA PER HOUR TO FURNACE WALL SURFACE OF STANDARD WATER-TUBE BOILERS

Millions B.t.u. liberated per hour in furnace	Furnace-wall surface in sq. ft.					
	250	500	1,000	1,500	2,000	3,000
50	29,300	21,800	16,400	13,600	11,400	8,400
100	49,500	41,000	31,000	24,600	20,500	15,200
150	66,000	55,500	42,200	34,200	29,500	22,300
200	77,200	67,300	52,600	43,400	36,700	28,600
250	90,700	79,000	61,800	51,000	44,000	34,000
300	98,600	86,200	69,400	58,500	51,000	39,200

This table is based on boiler having 480 sq. ft. of projected area exposed to radiation in the furnace.

In order to avoid misunderstanding in speaking of water-screen surfaces, it may be advisable to establish a standard for denoting which surface is to be used in specifying the number of square feet of effective heating surface of a water screen for a boiler furnace. The author would suggest that the projected area be used which for tubes is equal to the tube diameter multiplied by the length exposed.

Most Advantageous Amount of Radiant Heat-Absorbing Surface in a Furnace

In order to obtain the highest furnace temperature and the correspondingly highest efficiency, it is desirable to have the most rapid ignition and combustion possible. The coal entering the furnace must first be heated and any moisture in the coal must vaporize before combustion can begin. The burning gases must furnish the heat to raise the temperature of the coal and to evaporate the moisture. Some of this heat is absorbed by radiation from the surrounding walls, if they are not water-cooled, but even in this case the greater part comes from the flames of the burning gases. When the coal is heated up to about 400 deg. fahr. the gases and volatile vapors are given off from the coal before combustion starts.

Coal, being a black body, readily absorbs radiant heat, thus increasing in temperature. The gases of distillation also absorb more heat by radiation. After the gases and the admitted air have reached the ignition temperature, the combustion of the gases commences. The burning volatile matter produces water vapor and carbon dioxide, both of which will absorb and also radiate a considerable amount of radiant energy. Experiments have shown that luminous flames with particles of carbon floating in them radiate more heat than non-luminous flames. With pulverized fuel more radiant heat may be absorbed from the flames than with underfeed stokers, due to a larger volume of flame of greater luminosity.

On the other hand, in a pulverized-fuel furnace such solid particles as coke, burning carbon, and incandescent ash are in the path of radiation from the interior portions of the flame, and either absorb or reflect this radiant heat. It is logical to assume, therefore, as already mentioned in a previous paragraph, that the furnace walls affect only the radiation of a relatively thin envelope of the furnace flame and that the interior of the furnace is affected but little, if at all, by wall conditions. Many examples prove this. This is of considerable importance, as it tends to show that wall temperatures cannot affect the conditions in the whole furnace, a question which is in everybody's mind in considering water-cooled walls.

The amount of water-cooled surface that can be installed without lowering the furnace temperature to a point where combustion will be affected is dependent upon the kind of coal used, particularly upon the kind and quantity of volatile matter and of ash in the coal, and also upon the amount of moisture. All of these are important factors in the ignition temperature and affect the inflammability of the coal. The fusing temperature of the ash is also to be taken into consideration with respect to the slagging of the tubes.

In regions where only low-grade coal is available, difficulties have been experienced with the furnace walls, even when air-cooled. The refractory is eroded rapidly by the fused ash. Air-cooling of the side walls becomes effective only when the thickness of the refractory is somewhere between one and two inches, which is difficult to maintain. It is therefore very desirable when low-grade coal is used to keep the walls cool by water tubes. Enough refractory must be in the furnace, however, to reflect sufficient heat so that the temperature of the gases throughout the entire furnace is not lower than that required for combustion. The opinions of engineers vary widely regarding the amount of refractory or brick surface required in a furnace burning low-grade coal. Many believe that brick walls are needed as reflecting surfaces to accelerate the ignition and combustion of the coal, and that water-cooled walls would absorb too much radiant heat and cause incomplete combustion. As shown above, only the outer envelope of the furnace flames is affected by the cooling action of the tubes. If mixing of the air and gases could be maintained so that there would be an interchange between the gas near the walls and that in the center of the furnace, the ill effect of the water tubes could be minimized considerably. Preheated air would also reduce this effect.

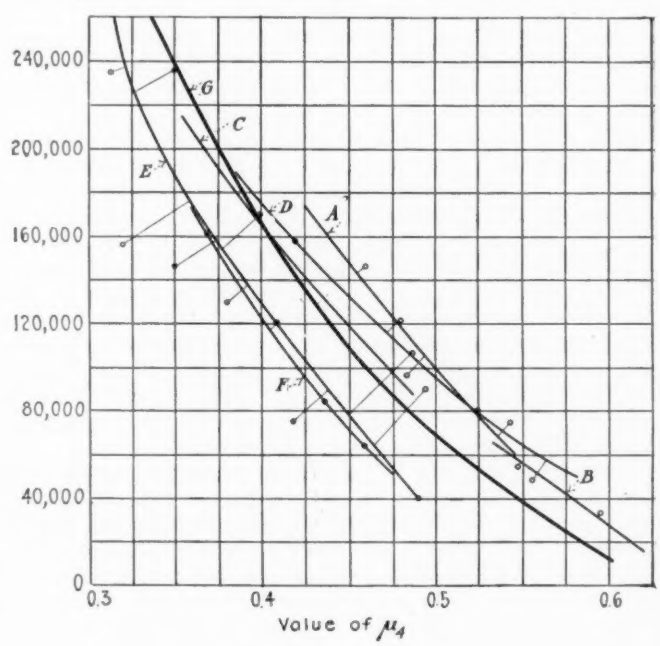


Fig. 2 Values of μ_4

It is usually thought that water-cooled walls should be used

with pulverized fuel and that they are less necessary with stokers. We need only consider the fact that in stoker furnaces pressures higher than the atmosphere occur which have a very ill effect on the brickwork, particularly if the temperature is very high, to understand that from this point of view water-cooled walls are more beneficial for stoker-fired than for powdered-coal furnaces.

Investigations with the burning of coal in furnaces have shown that anything that will burn at all will ignite in an ordinary furnace temperature of about 2000 deg. fahr.; that the question of combustion is not how to combine the oxygen and carbon when brought together, but how to bring them together. At ordinary furnace temperatures, the speed of the reaction between oxygen and carbon is so great that these elements will combine practically instantaneously. The main problem is to bring the particles together or to mix the oxygen and carbon, which requires time and space. Temperature has little effect on the mixing. It seems, therefore, that the furnace temperature can be reduced by heat-absorbing surface without affecting the combustion, if means are provided for the proper mixing of air and fuel.

Water-cooled furnaces naturally permit higher boiler capacities for the same boiler and the same furnace volume, as the rate of heat absorbed by the water-cooled tubes in the furnace is very high. Where water-cooled walls are used and the average temperature of the furnace is lower, no trouble is experienced with the erosive effect of the gases, and probably little trouble will be experienced with slag. The average higher capacity per square foot of heating surface would enable one to design the boiler proper with less heating surface, which results also in reduction of brickwork, as well as in height of boiler and boiler room.

The greater the amount of moisture in coal, the more heat must be absorbed before the coal is elevated to the ignition temperature. This applies also to the amount of ash in the fuel. On the other hand, the greater the volatile hydrocarbon content of the coal, the easier it will ignite. These naturally have an effect on the amount of cooling surface that can be arranged in a furnace.

The greater the amount of volatile matter, the more heating surface can be installed in the furnace; but the greater the ash or moisture content, the higher is the furnace temperature required, and the more dependent we are upon the reflected heat from the brick, with the result that less water-cooled surface should be provided. Where coal with a low fusing point of ash is used, water-cooled walls reduce the clinkering and slagging.

There is one factor in connection with water-cooled walls which does not seem to have been given any attention. It is a fact that the water-cooled furnace lacks the heat storage capacity which is usually present in a brick furnace. A furnace with a large heat storage capacity does not lend itself well for control of furnace operation. On the other hand, however, it enables the rapid increase of rating when so desired. This may be of considerable importance for power stations with high peak loads.

To sum up: Where coal which has a moisture content not greater than 4 per cent, a volatile content of approximately 20 per cent, and an ash content of not more than 7 or 8 per cent is burned in pulverized form, there is no reason why the furnace cannot be completely covered with water-cooled surfaces. For the same coal burned on stokers, it would be advisable to have the lower part of the furnace lined with brick in order to accelerate combustion on the stoker. With coal containing moisture up to 10 per cent and ash from 7 to 10 per cent, about 20 to 25 per cent of the surface will have to be of refractory unless means are provided for effectively mixing the gases in the furnace. It appears, however, that with coal having 25 per cent of moisture or a very high ash content it is not advisable to have more than two sides of the furnace water-cooled; when burned in pulverized form the bottom may also be water-cooled. In some cases it will be necessary also to fill in the spaces between the tubes of the side walls with brick. With preheated air the amount of cooled surface can be increased in every case.

There is a noticeable tendency toward large furnaces with a maximum possible amount of radiant-heat-absorbing surface, particularly where coal with low moisture and ash content is used. Most of the steam is generated by this surface in the furnace, and the gases are there cooled to a temperature at which no more heat can be absorbed by radiation than by convection. They pass then to a comparatively small boiler section where the remainder of the steam is generated. They are usually provided with an air heater to raise the air for combustion to high temperature. It is understood that such a boiler is now being built in Great Britain.

There are different arrangements of water-cooled walls. Fig. 3 shows a stoker-fired boiler with side walls as installed in the Hell Gate Station of the United Electric Light & Power Company, New York. The wall consists of 4-in. tubes arranged vertically on each side of the furnace and spaced on about 7-in. centers. Each tube has two longitudinal steel fins welded on it diametrically opposite each other, and when placed in the boiler furnace the fins of the adjacent tubes butt up against each other or overlap, thus

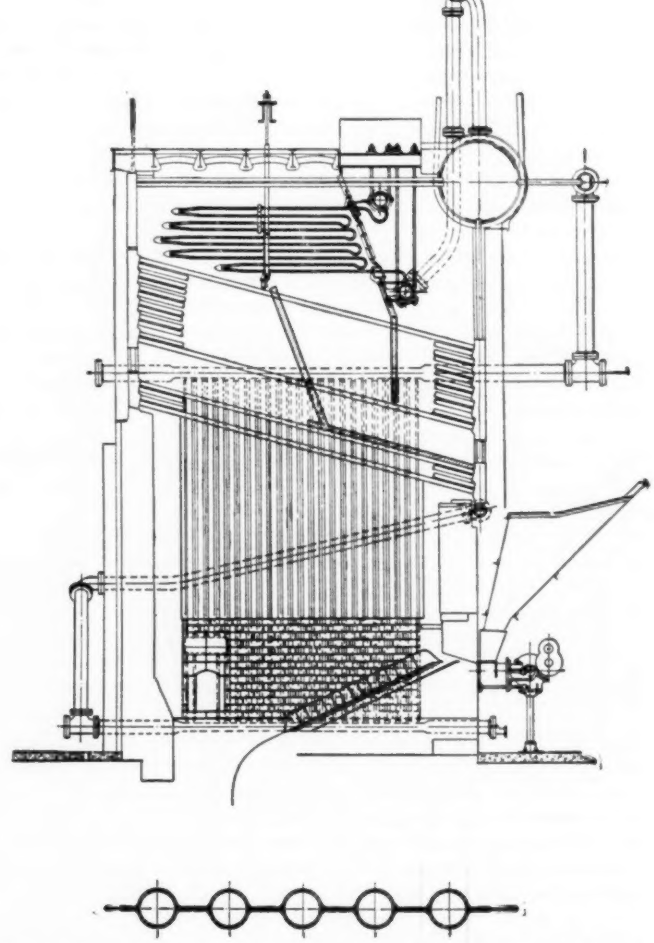


Fig. 3 Horizontal Water-Tube Boiler with Side Walls Made of Four-Inch Tubes with Welded-on Fins

presenting a continuous water-cooled surface to the radiant heat of the furnace. The lower portion of the tubes is covered by fireclay tile for a short distance above the stoker, and extends along a horizontal line the entire length of the furnace.

Fig. 4 indicates another design of water-cooled furnace walls. These walls, in accordance with the statement of the manufacturer, consist of steel tubes on which are shrunk heavy rectangular cast-iron blocks about 6 in. long and 4 in. wide. These elements are installed on close centers so that the open space between adjacent elements is approximately $^1/_8$ in. The faces toward the fire form a continuous flat wall.

Another design has been suggested consisting of steel tubes imbedded in the wall, with cast-iron blocks fastened to them facing the furnace. These blocks can be partially covered with refractory material in order to reduce the surface exposed direct to radiation.

Some of the above designs of water-cooled walls have heat-absorbing surfaces exposed to the furnace but not cooled directly by water. For these cases a certain factor must be introduced, depending upon their design, in order to determine the heat absorbed by radiation when a value μ_4 of Fig. 2 is used, as these values apply to surfaces directly cooled by water.

Effect of Gas Radiation on Heat Transmission

Tests with steam boilers have shown that the coefficient of heat transmission per square foot per degree of temperature difference per hour varies with the temperature difference, and is considerably higher than at lower differences. It was rather difficult to understand this phenomenon, as one would expect from the nature of heat transmission by convection that at higher temperature differences the coefficient would decrease. However, it has been conclusively proved recently that the increase of heat transmission with the higher temperature difference is due to the radiation of gases.

Of particular interest is the effect of radiation of gases in connection with the heat transmission in a steam boiler, which will be shown by the following example.

Two points of the path of the gases in the boiler were selected

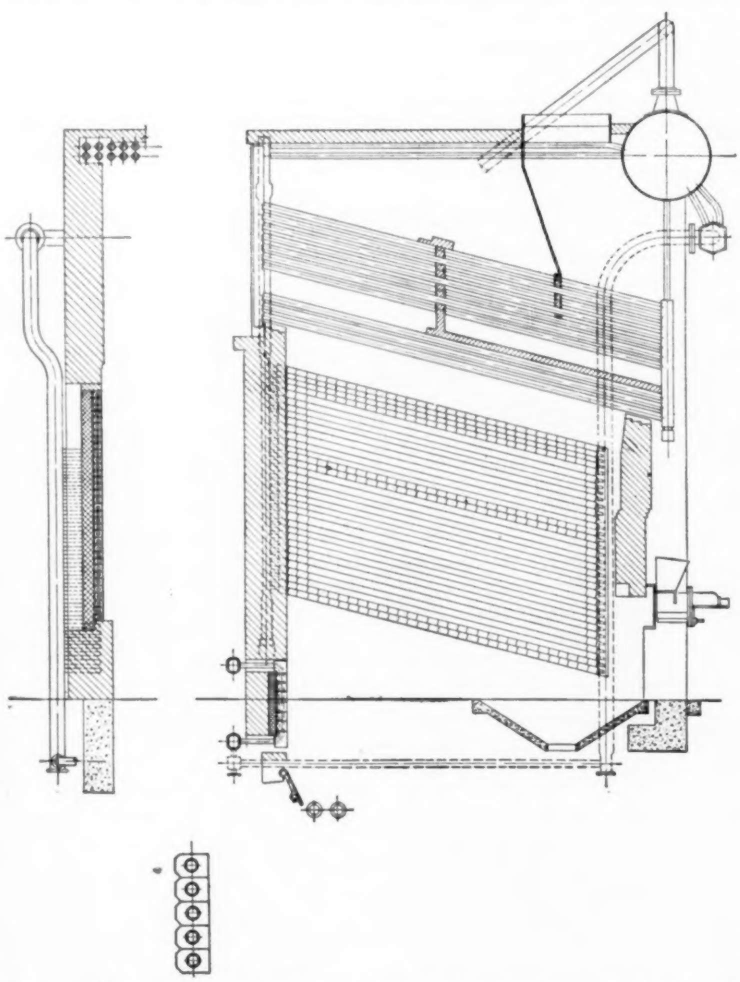


Fig. 4 Water-Cooled Walls Consisting of Steel Tubes on Which Are Shrunk Cast-Iron Blocks

where the temperatures were 1400 and 800 deg. fahr., respectively. From experiments, the heat transferred with 6000 lb. of gases per sq. ft. of area will be about 7.7 B.t.u. per deg. temperature difference per hr. at the 1400-deg. point. With 250 lb. pressure the temperature of the water is about 406 deg. The metal temperature of the tubes follows very closely the temperature of the water, so that the temperature difference between the tubes and the gases will be 994 deg., or a total heat transmission of 7660 B.t.u. per sq. ft. per hr. At the 800-deg. point the heat transfer rate is 6.65 with a temperature difference of 394 deg., giving a heat transmission of 2620 B.t.u. per sq. ft. per hr. Assuming the flue gases to contain 15 per cent CO_2 and 6 per cent H_2O, and the thickness of the gas layer to be about six inches, the following table of values at 1400 and 800 deg. may be computed:

	1400 deg.	800 deg.
Total B.t.u. transmission per sq. ft. per hr.	7660	2620
B.t.u. radiated by CO_2 per sq. ft. per hr.	1340	280
B.t.u. radiated by H_2O per sq. ft. per hr.	477	107
B.t.u. radiated by CO_2 plus H_2O per sq. ft. per hr.	1817	387
B.t.u. by convection only, line 1 minus line 4	5843	2233
B.t.u. transmitted by convection only per sq. ft. per hr. per deg. temperature difference	5.88	5.66

The figures indicate that it may be safely assumed that heat radiation is a considerable factor in the heat absorption by a boiler. It becomes necessary to consider the heat transfer from gases as consisting of two components, one showing the law of convection and the other the law of radiation. As the heat transmitted by convection varies with the velocity of the gases while the radiant heat is independent of this factor, it is important to have high velocity of the gases only where the heat absorbed by convection is dominating. This is of considerable interest in determining the area of the flow of gases in a boiler. An increase in velocity of the gases will increase the heat transmission only in the last passes of the boiler where the radiation is very low and most of the heat is transmitted by convection, so that it is advisable to have the gases pass over the heating surface with the highest possible velocity and in streams of small area. In the passes nearer to the furnace where the gas temperatures are high, it is rather desirable to have the gases flow with low velocity and in streams of large area in order to increase the radiant effect and, due to being in the pass a longer time, make it possible to give off a considerably greater amount of heat.

Extensive experiments on different boilers have been made by H. Kreisinger and J. F. Barclay on the influence of radiation in measuring the temperature of boiler flue gases. Two series of hot junctions were compared with each other at different points in each boiler. One junction was made of wires 0.08 in. in diameter and the other made as a tube 0.5 in. in diameter. By extrapolation the experimenters also estimated the true gas temperature. The variations obtained with the thick junction indicated what a large error may be incurred by using the pyrometer enclosed in a tube of $1^1/_2$ in. diameter if not shielded from the radiation from the cold tube surface. This error can be reduced by arranging a small screen of asbestos or refractory material around the bulb or junction, without unduly preventing the gases from coming into true contact with it.

Discussion

Written discussions were presented by George A. Orrok,[2] Walter J. Wohlenberg,[3] Edward H. Tenney,[4] Andrew A. Bato,[5] and F. F. Uehling.[6]

In Mr. Orrok's discussion, data on three designs of locomotive boilers, four water-tube boilers, and one revolving Atmos boiler were presented. From such a collection of data he stated it should be possible to work out a formula which would permit of results being predicted with a reasonable degree of accuracy, and at the same time permit of the checking up of boiler tests when the radiant surface was not isolated from the circulatory system of the boiler; and also would allow for the determining of the convection fraction of the heat and the temperatures which might be observed in the tube bank and uptakes.

The following modified Hudson's formula is one that was worked out and proved by Mr. Orrok:

$$X = C_r H_a \left(\frac{1}{1 + \frac{A\sqrt{C_r}}{27}} \right)$$

In this formula

X = heat transmission per square foot of radiant surface per hour

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[3] Asst. Prof. M.E., Sheffield Scientific Sch., Yale Univ. Mem. A.S.M.E.

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[5] Mech. Designer, Pub. Serv. Prod. Co. Assoc-Mem. A.S.M.E.

[6] Pres., and Comb. Engr., Uehling Instrument Co., Paterson, N. J. Mem. A.S.M.E.

C_r = pounds of coal per square foot of radiant surface per hour
H_a = available heat per pound of coal
A = pounds of air per pound of coal.

This formula checks very well with all the data which have been secured up to date, including those by Wohlenberg and by Broido; furthermore it is simple, may be quickly used with the slide rule, and gives all necessary quantities to check a complete boiler test or a new design.

Prof. A. G. Christie[7] made a few remarks from the floor in connection with Mr. Broido's paper. He stated that Mr. Broido had suggested that the cooling effect was probably confined to a narrow envelope along the side wall. Although this was also Professor Christie's opinion a year ago, he now had reason to question its validity.

Further, he stated that he had no data by which to decide whether gases were transparent or not to radiant heat. He was also inclined to question the accuracy of the observed temperatures near the water-cooled walls, as they were taken by a thermocouple, which, being a good radiating medium, would cast doubt on the readings taken with it.

Neither did Professor Christie agree with Mr. Broido's suggestion that the projected area of the tubes be measured as the heat-absorbing surface; he would prefer instead to take the whole of the heating surface.

It was Professor Christie's belief that increased ratings could be more quickly obtained with furnaces with water-cooled walls than with furnaces with brick walls that act as heat storers. He would expect the furnace with the least heat capacity in the walls to respond more rapidly to changes in radiation.

Answering Professor Christie's remarks, Mr. Broido stated that he considered that gases do not reflect and are not transparent to heat coming from another source, and believed that the temperature inside of the furnace near the wall was appreciably higher than might be expected, taking into consideration the heat absorbed or the water evaporated by the water tubes.

Regarding the tests, the temperatures might not be quite correct, but at least they showed the way in which these temperatures increased.

Professor Wohlenberg in his discussion stated that the Society was indebted to Mr. Broido for his contribution to the literature on the subject; that he had brought some very important facts to the attention of engineers, and that designers of steam generators would do well to study carefully the whole of the paper. He considered the matter pertaining to the radiating powers of gases at high temperature (included in the last two paragraphs of the present abstract) of particular interest and value to those engaged in the design and manufacture of boilers and economizers. It appeared that by taking advantage of gaseous radiation a steam generator could be so proportioned as to yield a certain maximum efficiency with a certain minimum draft loss, and for a relatively low cost. The results of Dr. Schack's research reproduced in the appendix (omitted in the abstract) were of great value in dealing quantitatively with the radiation problems involved in the design of such a steam generator. It was interesting to note that the coefficients of gaseous radiation, used in the paper submitted at the last spring meeting by Wohlenberg and Morrow, agreed with the values found by the application of Dr. Schack's formulas mentioned above.

Mr. Tenney, in his discussion, mentioned the fact that some of the points touched on by Mr. Broido, more particularly with respect to furnace temperatures and their relation to furnace-wall construction, had been the subject of a great deal of study and experimentation in both the Cahokia and Ashley Street Stations of the Union Electric Light & Power Co., of St. Louis.

Mr. Broido's paper impressed him with the fact that the problems which designers and operators of furnace equipment had to meet were problems which were bound to vary with the characteristics of the fuel, and that the conditions to be met would in almost every case require individual treatment. He considered the information contained in the paper as covering in a very excellent manner many of the points which must be considered in these studies.

Mr. Bato presented additional considerations concerning the radiation of the flame in the boiler furnace which were intended to prove certain facts indicated in the paper, and were also meant as suggestions for future research work.

Mr. Uehling made a few remarks intended to clearly bring out the difference between the terms "flame temperature" and "furnace temperature," which were sometimes confused. He pointed out that Mr. Broido had illustrated this point exceptionally well in Fig. 1 (of the abstract). There the horizontal line A represented the mean flame temperature, entirely independent of the rate of combustion, while the curves B and C representing mean furnace temperatures were decidedly influenced by this rate.

He defined the flame temperature as the temperature of the products of combustion caused by the chemical reaction between the combustible and the air at the instant the reaction occurred. This temperature, therefore, would depend only on the kind of fuel used on the temperature of the entering air, and on the analysis of the products of combustion. On the other hand, the mean furnace temperature would always be lower than the mean temperature of the chemical reaction between the fuel and the air, and would depend primarily upon how much heat was radiated in the furnace after the reaction had taken place. This distinction he had mentioned was of particular importance in the study of furnace radiation.

[7] Prof. M.E., Johns Hopkins Univ., Baltimore, Md. Mem. A.S.M.E.

A SERIES of experimental investigations of the properties of ammonia have been completed in the laboratories of the Bureau of Standards. These investigations are a part of a broader program of determining the fundamental thermodynamic properties of fluids with special reference to their use in engineering. Measurements to an accuracy of about one part in a thousand in general were made upon ammonia of a known and high degree of purity. The measurements extended over or beyond the range of pressures and temperatures ordinarily encountered in engineering practice, namely 0.5 to 20 atmos. pressure, —50 deg. to +50 deg. cent. (58 to 122 deg. fahr.) for the saturated fluid, and —40 deg. to +150 deg. cent. (—40 to +302 deg. fahr.) for the superheated vapor.

The experimental work consisted primarily of measurements on the following properties of ammonia: (1) specific heat of saturated liquid, (2) latent heat of vaporization, (3) vapor pressure, (4) specific volume of saturated liquid, (5) specific volume of saturated vapor, (6) specific heat of superheated vapor at constant pressure, and (7) specific volume of superheated vapor. Less precise measurements were made on a few other properties in order to provide the data required for the evaluation of certain correction terms needed in computing the results of the principal experiments.

The results of measurements of the seven properties enumerated above form the basis for tables and charts of the thermodynamic properties of ammonia which have been published for use in refrigerating engineering. For the sake of consistency and for convenience in computing the numerical data given in these tables, a set of empirical equations was formulated. Within the range covered by the experiments these equations are consistent with the laws of thermodynamics and express the experimental results within the limits of accuracy estimated by the observers. The fact that it was found possible to so represent all of the data obtained from accurate measurements of a group of closely related properties, is a check in itself on the accuracy of the data.

As a result of this work it is now possible to compute any one of the various thermodynamic derivatives and to evaluate all of the purely thermodynamic properties of ammonia with considerable confidence in the range covered by the experiments. In this paper, values of three of these properties—the specific heat at constant volume, the ratio of specific heats, and the Joule-Thomson coefficient—are evaluated in this manner and compared with experimental values obtained by various observers. Since the experimental data available on these three properties by numerous observers had been given no direct consideration or weight in formulating the properties of ammonia, the very satisfactory agreement between the observed and computed values of these properties, as pointed out here, constitutes an independent check on the accuracy of the Bureau's experimental data. (C. S. Cragoe, Physicist, Bureau of Standards, Washington, D. C., in *Refrigerating Engineering*, vol. 12, no. 5, November, 1925, pp. 131–142, *e*)

The Ring Spring

Characteristics and Advantages of a Type of Compression Spring Consisting of an Assembly of Alternate Inner and Outer Rings, Each Coacting with the Adjacent Ones along Conical Surfaces—Design Formulas and Illustrative Calculation

By O. R. Wikander,[1] Pittsburgh, Pa.

In all springs in common use today the metal is subjected to torsional or bending stresses, the coil spring being a typical case where the main stresses are torsional, and the leaf spring one where they are flexural. In both cases the stressing efficiency[2] is rather low, because the maximum permissible stress occurs only on the surface of the bar and decreases toward the interior, reaching zero in the neutral axis or zone.

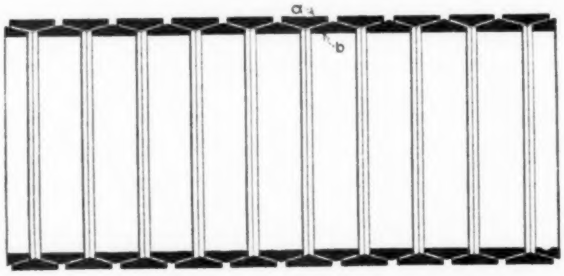

Fig. 1 Longitudinal Section of a Ring Spring

In the case of the round-bar coil spring, the highest stressing efficiency obtained amounts to 50 per cent, while for the rectangular-bar cantilever spring it is only 10 per cent. The ring spring is the successful result of systematic efforts, extending over a number of years, to produce a spring in which all fibers would be stretched uniformly, thus obtaining a stressing efficiency of about 100 per cent.

Fig. 2 View of Assembled Ring Spring

As illustrated in Fig. 1, the ring spring consists of a number of outer and inner closed or solid rings, *a* and *b*, each ring coacting with the adjacent ones along conical surfaces.

Fig. 2 is a view of the assembled spring, while one each of its constituent parts, an outer ring, an inner ring and an inner half-ring, are illustrated in Fig. 3.

When axial pressure is applied, the rings telescope into each other, the outer rings being subjected to practically uniform tensile stresses and the inner ones to equally uniform compression stresses. As the rings are made of highly elastic material, the outer rings will expand, the inner rings will compress, and each conical surface will telescope into the adjacent one a certain distance in the axial direction. The travel taking place between each pair of conical surfaces, or in each "spring element," as the halves of two coacting adjacent rings are called, added to the travels of the other elements, form the total travel of the spring.

General Characteristics of the Ring Spring

The outstanding feature of the ring spring that distinguishes it from all earlier spring designs is, as stated above, that every fiber of the material is stretched or compressed to what the designer considers to be the safe limit when the spring is subjected to its maximum load.

For this reason the amount of work that can be stored in a ring spring at given maximum stresses is much higher per cubic inch or per pound than for any other type of spring.

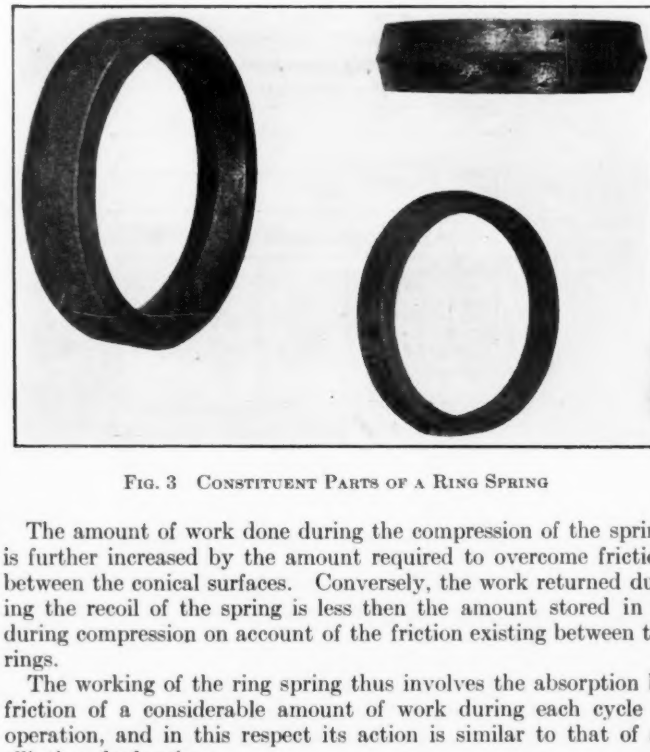

Fig. 3 Constituent Parts of a Ring Spring

The amount of work done during the compression of the spring is further increased by the amount required to overcome friction between the conical surfaces. Conversely, the work returned during the recoil of the spring is less then the amount stored in it during compression on account of the friction existing between the rings.

The working of the ring spring thus involves the absorption by friction of a considerable amount of work during each cycle of operation, and in this respect its action is similar to that of an elliptic or leaf spring.

On account of its high stressing efficiency, however, its weight is only about 10 per cent of that of an equivalent leaf spring.

Formulas for the Calculation of Ring Springs

An exact mathematical analysis of the stresses occurring in the ring spring is, just as in the case of other springs, so complicated as to be of little practical value, and therefore simpler and approximate methods are used, which experience has proved to be sufficiently exact for all practical purposes.

The following formulas do not take into account the bending stresses which are due to the changes of the diameters of gyration of the rings caused by their expansion and contraction. These stresses may be neglected in cases where the radial thickness of the spring is small and the inside diameter amounts to 80 or more per cent of the outside diameter. In case of thicker springs these stresses will have to be taken into account as they decrease the stressing efficiency of the spring to an appreciable degree.

Fig. 4 shows in cross-section a single ring-spring element. The dimensions indicated, together with the number of elements, fully determine the design of a ring spring.

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[1] Consulting Engineer, Edgewater Steel Co.

[2] A quantitative term recently devised and used by J. Kaye Wood in connection with mechanical springs. In his paper "Code of Design for Mechanical Springs" (Mechanical Engineering, September, 1925, p. 713), Mr. Wood takes pure tension as the basis for computing stress efficiency, because all fibers in such a case are stressed to a maximum permissible amount.

Contributed by the Special Research Committee on Metal Springs and presented at the Annual Meeting, New York, November 30 to December 4, 1925, of The American Society of Mechanical Engineers.

Using inches and pounds as units, the following designations have been adopted:

D = outside diameter of the outer ring
D_1 = inside diameter of the outer ring
d_1 = diameter of gyration of the outer ring
D_2 = outside diameter of the inner ring
d = inside diameter of the inner ring
d_2 = diameter of gyration of the inner ring

(Dimensions apply to unloaded springs)

b = half the width of one outer ring
= half the width of one inner ring
$\tan\alpha$ = taper of the conical surfaces
φ = coefficient of friction
P_0 = ultimate elastic resistance of a compressed spring (or the ultimate resistance the spring would offer to compression if the coefficient of friction were zero)
P = ultimate resistance of compressed spring
P_1 = initial recoil force of compressed spring
n = number of spring elements
f = maximum travel of each spring element
F = total deflection or travel of spring
W_0 = elastic work done during the compression of spring
W = actual work done during the compression of spring
W_1 = actual work returned during the recoil of spring
E = tensile modulus of elasticity
A_1 = sectional area of an outer-ring element
V_1 = volume of an outer-ring element
g_1 = weight of an outer-ring element

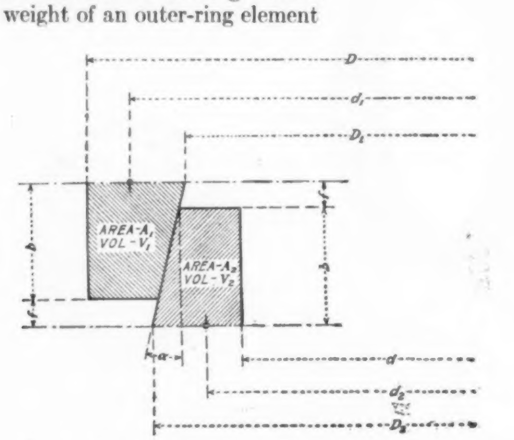


FIG. 4 CROSS-SECTION OF A SINGLE RING ELEMENT

A_2 = sectional area of an inner-ring element
V_2 = volume of an inner-ring element
g_2 = weight of an inner-ring element
V = total volume of ring spring
G = total weight of ring spring
S_1 = maximum average tensile stress in outer ring
S_2 = maximum average compression stress in inner ring
S = maximum average of all the stresses in both outer and inner rings.

$$c = \frac{\tan\alpha + \varphi}{\tan\alpha\,(1 - \varphi\tan\alpha)}$$
$$c_1 = \frac{\tan\alpha - \varphi}{\tan\alpha\,(1 + \varphi\tan\alpha)}$$

(Constants used in some of the ring-spring formulas)

In order to develop a formula for the calculation and design of a ring spring, it is convenient to start from the consideration that the work stored in the compressed spring is equal to the external work which would be done in compressing it, were there no friction.

The work stored in every volume element of a compressed spring is, however, equal to the volume of the element multiplied by the square of the occurring stress and divided by twice the modulus of elasticity. Hence in the case under consideration,

$$\frac{V_1 S_1^2}{2E} = \text{work stored in one outer-ring element}$$

$$\frac{V_2 S_2^2}{2E} = \text{work stored in one inner-ring element.}$$

Assuming the same modulus of elasticity for tension and compression, the total amount of work stored is

$$W_0 = n\,\frac{V_1S_1^2 + V_2S_2^2}{2E} = \frac{P_0 \times F}{2} \qquad [1]$$

On account of the friction, however, the force required to compress the spring is increased, while the recoil force is decreased. Analysis of the forces occurring will show that

$$P = \frac{\tan\alpha + \varphi}{\tan\alpha\,(1 - \varphi\tan\alpha)} \times P_0 = cP_0 \qquad [2]$$

and

$$P_1 = \frac{\tan\alpha - \varphi}{\tan\alpha\,(1 + \varphi\tan\alpha)} \times P_0 = c_1 P_0 \qquad [3]$$

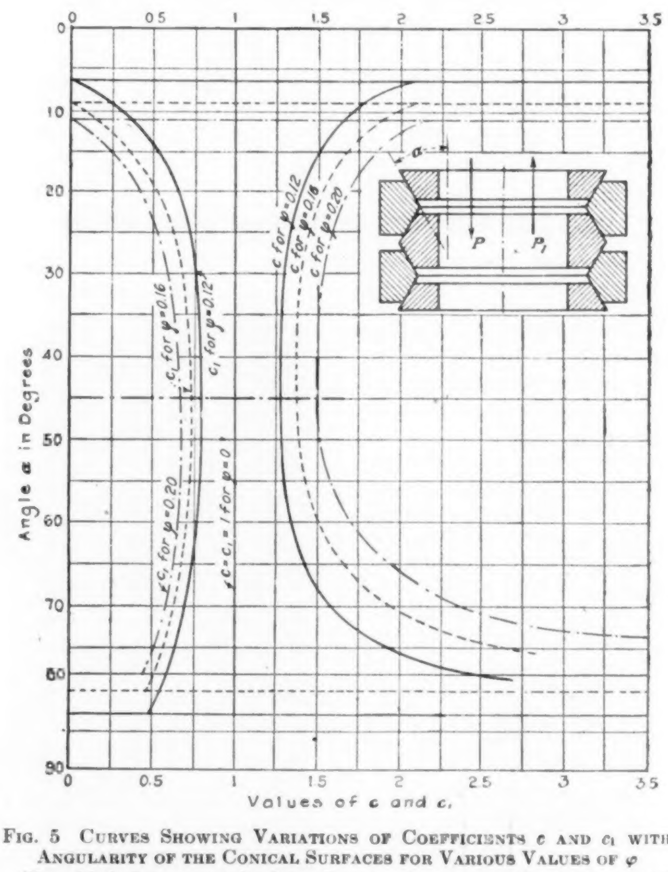


FIG. 5 CURVES SHOWING VARIATIONS OF COEFFICIENTS c AND c_1 WITH ANGULARITY OF THE CONICAL SURFACES FOR VARIOUS VALUES OF φ

(P_0 = frictionless compression force; P = actual compression force; P_1 = actual recoil force; φ = coefficient of friction; $c = P/P_0$; $c_1 = P_1/P_0$.)

The curves in Fig. 5 show how the coefficients c and c_1 vary with the angularity of the conical surfaces for various constant values of φ (0.12, 0.14, and 0.16).

The value of φ varies from as low as 0.09 for freshly lubricated springs up to 0.16 for rusty and dirty springs without lubrication. Experience has shown that in most applications $\tan\alpha = 0.25$ [α (Fig. 4) = 14°] will insure a positive release of the spring.

Assuming $\tan\alpha = 0.25$, or a taper of 1 to 4, the curves in Fig. 6 give the values of c and c_1 for various values of the coefficient φ. The curves are drawn with the ratio P_1/P as abscissa for the sake of convenience when analyzing test results.

In designing a ring spring for a given service, the travel and the ultimate resistance are generally given. The outside diameter and the solid height are preferably made as large as the conditions will permit. The solid height should be at least four times the travel of the spring.

From the known values of P and F, the amount of work done during the compression of the spring is found to be

$$W = PF/2 \qquad [4]$$

and the corresponding amount of elastic work,

$$W_0 = W/c \qquad [5]$$

the coefficient c being computed from the values of φ and $\tan\alpha$ (see definition of c), or taken from the diagram, Fig. 6, if $\tan\alpha = 0.25$.

Assuming an average value S of the occurring stresses, the volume of a spring necessary in order to store the amount of work W_0 at the maximum average stress S can be computed as follows:

$$\frac{VS_2}{2E} = W_0 \text{ or } V = \frac{2\,EW_0}{S^2} \qquad [6]$$

The inside diameter d is found from the obvious formula:

$$\frac{\pi}{4}(D^2 - d^2)\,h = V; \text{ or } d = \sqrt{D^2 - \frac{V}{h}\cdot\frac{4}{\pi}} \qquad [7]$$

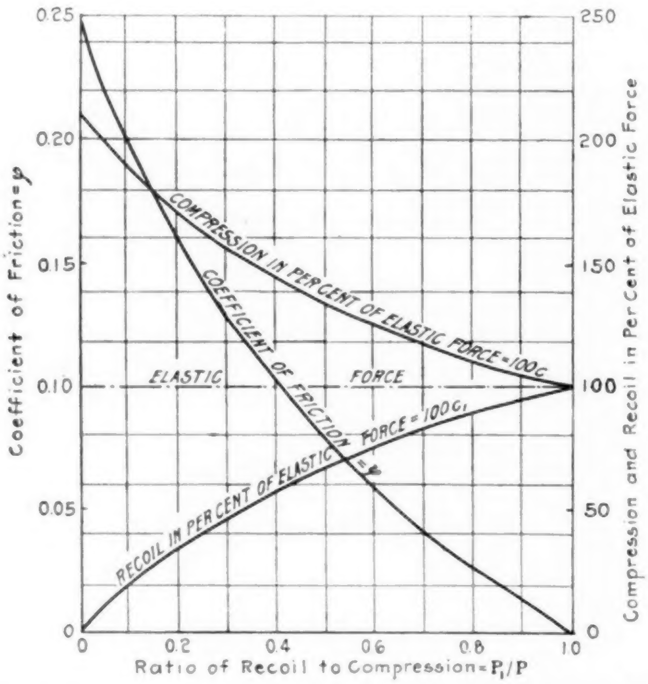


FIG. 6 VALUES OF c AND c_1 FOR VARIOUS VALUES OF φ WHEN TAN α = 0.25

The equilibrium of the internal forces in the spring is obtained by a distribution of the stresses according to the equation

$$S_1A_1 = S_2A_2, \text{ or } \frac{A_1}{A_2} = \frac{S_2}{S_1} \qquad [8]$$

The inner rings, which are subjected to compression only, may be stressed higher than the outer rings.

The ratio of the stresses can be controlled by the selection of a corresponding ratio of A_1/A_2.

The total travel per element is approximately

$$f = \frac{D+d}{2} \times \frac{S}{E\tan\alpha} \qquad [9]$$

and the required number of spring elements

$$n = F/f \qquad [10]$$

The nearest higher even number for n is generally selected, as an even number of elements will give two interchangeable half-rings, inner or outer ones, whichever is preferred.

After n has been decided upon, the travel f per element is found from Equation [10], or $f = F/n$.

It is now possible to lay out the spring according to Fig. 4 and to obtain exact values of A_1, A_2, D_1, D_2, d_1, and d_2. V_1, g_1, V_2, g_2, V, and G can also be computed.

The travel of the spring should be checked by means of the formula

$$f = \frac{d_1S_1 + d_2S_2}{2\,E\tan\alpha} \qquad [11]$$

and $F = nf$....according to Equation [10].

The exact values of W_0 and P_0 can be computed from Equation [1], and the values of P and P_1 then obtained from [2] and [3].

It is permissible to work the inner rings to their elastic limit, because no breakage is possible since these rings are subjected to compression only. The maximum stress in the outer rings, which are always in tension, should be kept sufficiently low to insure safe operation of the spring.

EXAMPLE ILLUSTRATING USE OF FORMULAS

The use of the foregoing formulas will be illustrated in analyzing the test results of a spring—shown in Fig. 7—which has been in satisfactory operation for over a year.

Fig. 8 shows the actual diagram obtained when this spring was tested in a standard testing machine.

The principal dimensions of the spring are as follows:

$D = 9.850$ in. $d = 8.470$ in.

$D_1 = 8.912$ in. $D_2 = 9.408$ in.

$b = \frac{1.575}{2} = 0.7875$ in. $\tan\alpha = 0.25$ $\varphi = 0.12$

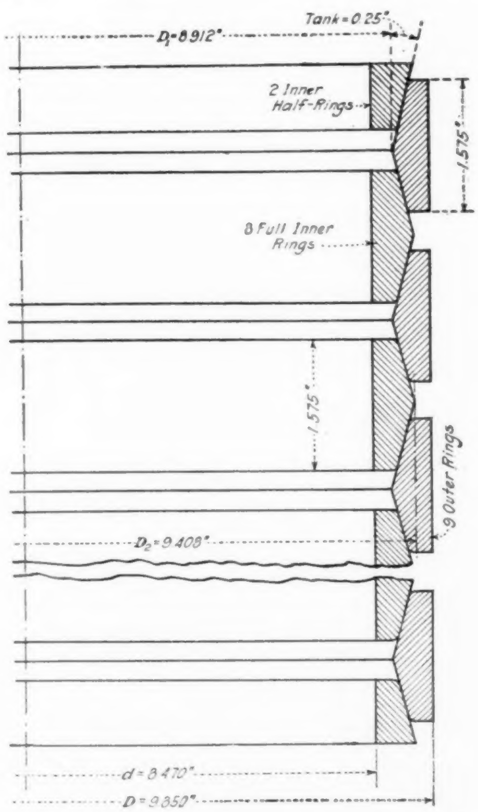


FIG. 7 LONGITUDINAL SECTION OF PART OF AN 18-ELEMENT RING SPRING USED SATISFACTORILY FOR OVER A YEAR

With sufficient approximation, we have:

$$d_1 = \frac{D + D_1 + b\tan\alpha}{2} = 9.480 \text{ in.}$$

$$d_2 = \frac{d + D_2 - b\tan\alpha}{2} = 8.840 \text{ in.}$$

Number of elements $n = 18$; weight of spring $G = 85.5$ lb.

Assuming the average value S of the occurring stresses = 160,000 lb. per sq. in. and $E = 29 \times 10^6$ lb. per sq. in., the total travel per element is found from Formula [9] to be

$$f = \frac{D+d}{2} \times \frac{S}{E\tan\alpha} = \frac{9.850 + 8.470}{2} \times \frac{160{,}000}{29 \times 10^6 \times 0.25}$$
$$= 0.202 \text{ in.}$$

and the total travel of the spring, according to Formula [10],

$$F = n \times f = 18 \times 0.202 = 3.636 \text{ in.}$$

From the dimensions given the cross-sectional area of each element can be computed as follows:

$$A_1 = \frac{D - D_1 - b \tan \alpha}{2} \times b = 0.292 \text{ sq. in.} \ldots\ldots [12]$$

and

$$A_2 = \frac{D_2 - d - b \tan \alpha}{2} \times b = 0.292 \text{ sq. in.} \ldots\ldots [13]$$

The areas A_1 and A_2 being equal, the average maximum stresses occurring in them will, according to Formula [8], also be equal, or

$$S_1 = S_2 = \text{average maximum stress } S$$

Formula [11] gives the exact travel per element: namely,

$$f = \frac{d_1S_1 + d_2S_2}{2\,E \tan \alpha} = \frac{9.480 \times 160{,}000 + 8.840 \times 160{,}000}{2 \times 29 \times 10^6 \times 0.25} = 0.202 \text{ in.}$$

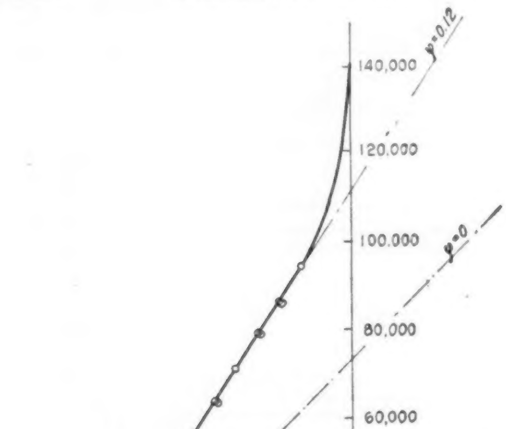


FIG. 8 ACTUAL DIAGRAM OBTAINED WHEN SPRING SHOWN IN FIG. 7 WAS TESTED IN A STANDARD TESTING MACHINE

(φ = coefficient of friction. Weight of spring = 85 lb. Work done during compression = 16,900 ft-lb.; work done during recoil = 5450 ft-lb.; work absorbed = 11,450 ft-lb.)

which checks exactly with the value found above from Formula [9], due to the fact that in this case $A_1 = A_2$.

The volumes V_1 and V_2 are computed as follows:

$$V_1 = d_1\,\pi\,A_1 = 9.480 \times \pi \times 0.292 = 8.71 \text{ cu. in.}$$
$$V_2 = d_2\,\pi\,A_2 = 8.840 \times \pi \times 0.292 = 8.12 \text{ cu. in.}$$

The elastic work W_1 is then computed from Formula [1]:

$$W_1 = n\,\frac{V_1S_1^2 + V_2S_2^2}{2\,E} = 18\,\frac{8.71 \times 160{,}000^2 + 8.12 \times 16{,}000^2}{2 \times 29 \times 10^6}$$

$$= 133{,}600 \text{ in-lb.}$$

and further:

$$P_0 = \frac{2\,W_a}{F} = \frac{2 \times 133{,}600}{3.636} = 73{,}500 \text{ lb.}$$

Assuming $\varphi = 0.12$ and $\tan \alpha = 0.25(\alpha = 14°)$, the constants c and c_1 can be found from the curves of Fig. 5, which gives

$$c = 1.52 \qquad\qquad c_1 = 0.49$$

According to Formula [2] the ultimate resistance obtained is

$$P = c \times P_0 = 1.52 \times 73{,}500 = 111{,}600 \text{ lb.}$$

and the initial recoil force, according to Formula [3], is

$$P_1 = c_1P_1 = 0.49 \times 73{,}500 = 36{,}000 \text{ lb.}$$

It will be seen that these values very closely check with those shown in the diagram of Fig. 8.

Actual tests of ring springs designed by the use of the above formulas show that their capacity per unit of weight is approximately three to four times that of the ordinary coil spring, and about ten times that of the elliptic or leaf spring.

POSTSCRIPT

After writing the above paper, the author decided to try to apply some recently published general spring formulas to the ring spring. This attempt led to such interesting results that it is considered worth while to record them.

In a paper[3] presented by Joseph Kaye Wood at the A.S.M.E. Spring Meeting, Milwaukee, Wis., May 18 to 21, 1925, a tentative code of design for mechanical springs was proposed. This code the author will follow in deriving the basic formulas for ring-spring calculation.

Mr. Wood developed in his paper the following formulas:

Load deflection rate:

Required		Constant		Material		Bar		Lever Ratio	
$\frac{P}{F}$	=	k	×	E	×	$\frac{A}{l}$	×	$\left(\frac{d}{D}\right)^2$	[I]

Safe maximum load:

$$P = m \times S \times A \times \left(\frac{d}{D}\right) \qquad [II]$$

Safe maximum deflection:

$$F = n \times \frac{S}{E} \times l \times \left(\frac{D}{d}\right) \qquad [III]$$

Safe maximum work:

$$W = \frac{u}{2} \times \frac{S^2}{E} \times Al \qquad [IV]$$

Total weight of spring:

$$G = Al \times \delta \text{ plus elastically dead material} \qquad [V]$$

The code contains also formulas for the weight per linear foot of bar and for the period of oscillation, but these will not be applied to ring springs in this paper.

BASIC FORMULAS FOR RING-SPRING CALCULATION

In the following these additional designations will be used:

$$\epsilon = \text{ratio } \frac{A_2}{A_1} = \frac{S_1}{S_2} \text{ (see Formula [8])}$$

$$\delta = \text{density of the spring material.}$$

Constants. Applying Formulas [I] to [V] to the ring spring, it is found that the constant n is always unity, while

$$k = m = u = \text{unity in case of a frictionless spring}$$
$$= c \text{ for the compression stroke and}$$
$$= c_1 \text{ for the recoil stroke.}$$

Material. In Formulas [II], [III], and [IV], S is the safe maximum stress. Applying them to ring springs, it is found convenient to figure with S_2, the maximum occurring stress in the inner rings, which is usually equal to the elastic limit of the material.

Bar. The equilibrium of the tangential forces is established when

$$A_1S_1 = A_2S_2$$

[3] A Code of Design for Mechanical Springs. See MECHANICAL ENGINEERING, September, 1925, p. 713.

or when the force stretching each outer element is equal to the force compressing each inner element. Mechanically the outer elements would act exactly as if the section of each were A_2 and the maximum stress S_2, if their diameters of gyration were reduced in the proportion of S_2 to S_1.

It is thus permissible to introduce in the above formulas

$$S = S_2,\ A = A_2, \text{ and } l = \pi n\ (\epsilon d_1 + d_2), \text{ where } \epsilon = S_1/S_2.$$

If the outside diameter D and the inside diameter d of a ring spring are given, the approximate values of d_1 and d_2 are:

$$d_1 = \frac{D + 2\ D\epsilon + d}{2\ (1 + \epsilon)} \quad [14]$$

$$d_2 = \frac{D\epsilon + d\epsilon + 2d}{2\ (1 + \epsilon)} \quad [15]$$

Lever Ratio. In the Formulas [I], [II], and [III] this ratio is equal to the ratio between the stretch of the bar and the corresponding travel of the spring.

It can be deduced that, in order to cause a travel of the ring spring of one inch, it is necessary to stretch (or compress) the bar $2\ \pi \tan \alpha$ inches. This is thus the lever ratio (d/D) used in the above formulas.[4]

Ring-Spring Formulas

Applying Mr. Wood's code to the ring spring, the following formulas are obtained:

Load-deflection rates:

$$\frac{P_0}{F} = 1 \times E \times \frac{A_2}{\pi n\ (\epsilon d_1 + d_2)} \times (2\ \pi \tan \alpha)^2 \quad [16]$$

$$\frac{P}{F} = c \times E \times \frac{A_2}{\pi n\ (\epsilon d_1 + d_2)} \times (2\ \pi \tan \alpha)^2 \quad [17]$$

$$\frac{P_1}{F} = c_1 \times E \times \frac{A_2}{\pi n\ (\epsilon d_1 + d_2)} \times (2\ \pi \tan \alpha)^2 \quad [18]$$

Maximum loads:

$$P_0 = 1 \times S_2 \times A_2 \times 2\ \pi \tan \alpha \quad [19]$$

$$P = c \times S_2 \times A_2 \times 2\ \pi \tan \alpha \quad [20]$$

$$P_1 = c_1 \times S_2 \times A_2 \times 2\ \pi \tan \alpha \quad [21]$$

Maximum deflection:

$$F = \frac{S_2}{E} \times \pi n\ (\epsilon d_1 + d_2) \times \frac{1}{2\ \pi \tan \alpha} \quad [22]$$

Maximum work:

$$W_0 = \frac{1}{2} \times \frac{S_2^2}{E} \times A_2 \pi n\ (\epsilon d_1 + d_2) \quad [23]$$

$$W = \frac{c}{2} \times \frac{S_2^2}{E} \times A_2 \pi n\ (\epsilon d_1 + d_2) \quad [24]$$

$$W_1 = \frac{c_1}{2} \times \frac{S_2^2}{E} \times A_2 \pi n\ (\epsilon d_1 + d_2) \quad [25]$$

The total weight of the spring material is

$$G = \pi n\ (A_1 d_1 + A_2 d_2) \times \delta \quad [26]$$

Many of the above quantities are practically the same for various ring-spring designs, and, if the following average values are introduced, very simple expressions are obtained:

$E = 28 \times 10^6$ $\quad S_2 = 180{,}000$ $\quad \tan \alpha = 0.25$

$\varphi = 0.12$ $\quad \epsilon = 0.75$ $\quad \delta = 0.2835$

$c = 1.53$

$c_1 = 0.505$

[4] NOTE. n, S, d, and D in Formulas [I] to [V], which are copied from the above paper of Mr. Wood, have different meanings from those of the same symbols as used by the author and defined early in the present paper.

Load-deflection rates:

$$\frac{P_0}{F} = 22 \times 10^6 \times \frac{A_2}{n(0.75\ d_1 + d_2)} \quad [27]$$

$$\frac{P}{F} = 33.6 \times 10^6 \times \frac{A_2}{n(0.75\ d_1 + d_2)} \quad [28]$$

$$\frac{P_1}{F} = 11.1 \times 10^6 \times \frac{A_2}{n(0.75\ d_1 + d_2)} \quad [29]$$

Maximum loads:

$$P_0 = 283{,}000\ A_2 \quad [30]$$

$$P = 432{,}000\ A_2 \quad [31]$$

$$P_1 = 143{,}000\ A_2 \quad [32]$$

Maximum deflection:

$$F = 0.01285\ n\ (0.75\ d_1 + d_2) \quad [33]$$

Maximum work:

$$W_0 = 1820\ (0.75\ d_1 + d_2)\ A_2 n \quad [34]$$

$$W = 2780\ (0.75\ d_1 + d_2)\ A_2 n \quad [35]$$

$$W_1 = 920\ (0.75\ d_1 + d_2)\ A_2 n \quad [36]$$

and the total weight

$$G = 0.892\ (A_1 d_1 + A_2 d_2) n \quad [37]$$

In cases where less frictional resistance is desired, it will be found advisable to increase the value of $\tan \alpha$ to $1/3$. Assuming that E, φ and S_2 remain the same, we have then:

$E = 28 \times 10^6$ $\quad S_2 = 180{,}000$ $\quad \tan \alpha = 1/3$

$\varphi = 0.12$ $\quad \epsilon = 0.75$ $\quad \delta = 0.2835$

$c = 1.417$

$c_1 = 0.615$

Load-deflection rates:

$$\frac{P_0}{F} = 39.2 \times 10^6 \times \frac{A_2}{n(0.75\ d_1 + d_2)} \quad [38]$$

$$\frac{P}{F} = 55.5 \times 10^6 \times \frac{A_2}{n(0.75\ d_1 + d_2)} \quad [39]$$

$$\frac{P_1}{F} = 24.1 \times 10^6 \times \frac{A_2}{n(0.75\ d_1 + d_2)} \quad [40]$$

Maximum loads:

$$P_0 = 377{,}000\ A_2 \quad [41]$$

$$P = 534{,}000\ A_2 \quad [42]$$

$$P_1 = 232{,}000\ A_2 \quad [43]$$

Maximum deflection:

$$F = 0.00965\ n\ (0.75\ d_1 + d_2) \quad [44]$$

Maximum work:

$$W_0 = 1820\ (0.75\ d_1 + d_2)\ A_2 n \quad [45]$$

$$W = 2580 \times (0.75\ d_1 + d_2)\ A_2 n \quad [46]$$

$$W_1 = 1120 \times (0.75\ d_1 + d_2)\ A_2 n \quad [47]$$

The total weight of the spring is found by means of Formula [37], which is independent of the taper of the conical surfaces.

Conclusion. The ring spring is a friction spring with high stressing efficiency, adapted to uses where high capacity, low weight, or small volume are desirable and where a considerable power absorption is not objectionable.

Progress Report on the Development of Steam Charts and Tables from the Harvard Throttling Experiments[1]

By J. H. Keenan,[2] Schenectady, N. Y.

At the December, 1923, meeting of the A.S.M.E., Dr. H. N. Davis and Dr. R. V. Kleinschmidt presented the results of their throttling experiments which were being carried on as a part of the A.S.M.E. Steam Research Program. The data covered a pressure range from 30 lb. per sq. in. absolute to 565 lb. per sq. in. absolute, and a temperature range from 332 deg. fahr. to 657 deg. fahr. (Fig. 1). Feeling that these data afforded a valuable

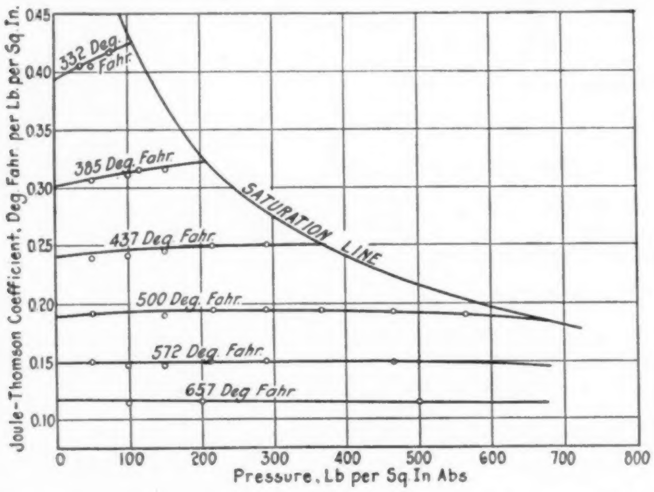


Fig. 1 Davis-Kleinschmidt Joule-Thomson Tests on Which Steam-Chart Development Was Based

opportunity to obtain some much-needed information on steam at high pressures, the General Electric Company took advantage of Dr. Davis's offer of the data and his aid to develop a steam chart.

The A.S.M.E. Committee on the Properties of Steam and the Extension of the Steam Table very kindly gave access to the data and has shown through its chairman, Mr. Orrok, a cordial interest in the work. Dr. Davis gave unsparingly of his time and efforts in the development of formulations and the elimination of difficulties, some of which he has already discussed before this Society.[3]

Preliminary Work

The development of the throttling-experiment data into a steam chart required some formulation of the data such that the Joule-Thomson coefficient for any temperature and pressure could readily be found. Such a formulation was devised by Dr. Davis for all pressures under 50 atmospheres throughout the superheated-steam region. The Joule-Thomson coefficients, which are simply values of the slope of constant-total-heat lines on a temperature-pressure plane, $\left(\frac{\partial T}{\partial p}\right)_H$, were then integrated by a finite-step process from zero absolute to 50 atmospheres pressure.

The result of this integration was the chart shown in Fig. 2. It was one of the most important parts of the development in that it served directly as the basis for determining total heat and was indirectly the basis for the calculation of entropy and specific volume.

The total-heat interval between any two constant-total-heat lines is, of course, the same at all pressures. Also the mean specific heat in that interval at any pressure is equal, very nearly, to the ratio of the total-heat interval to the temperature interval. Thus, between any two constant-total-heat lines the specific heat at constant pressure varies inversely as the temperature interval between the lines. This chart, then, affords a means of determining the values of the constant-pressure specific heat relative to the specific heat at the same total heat and at some reference pressure. The hypothetical pressure, zero absolute, was chosen as the reference pressure, and a chart was drafted showing throughout the superheated-steam region the ratio of the constant-pressure specific heat to the specific heat at zero pressure on the same constant-total-heat line (Fig. 3).

It was then necessary to find the basis from which the complete set of specific heats was to be found, or the hypothetical specific heat at zero pressure. This necessitated the introduction of some specific-heat determinations that were independent of the Joule-Thomson tests and each of which divided by the corresponding specific-heat ratio would give a value for the specific heat at zero pressure. The determinations used were principally those of Knoblauch and his collaborators and included their more recent work which had been carried to pressures as high as 420 lb. per sq. in. A few additional points were obtained from the work of Regnault and of Brinkworth. The zero-pressure specific-heat points so determined are shown in Fig. 4. The absence of any systematic

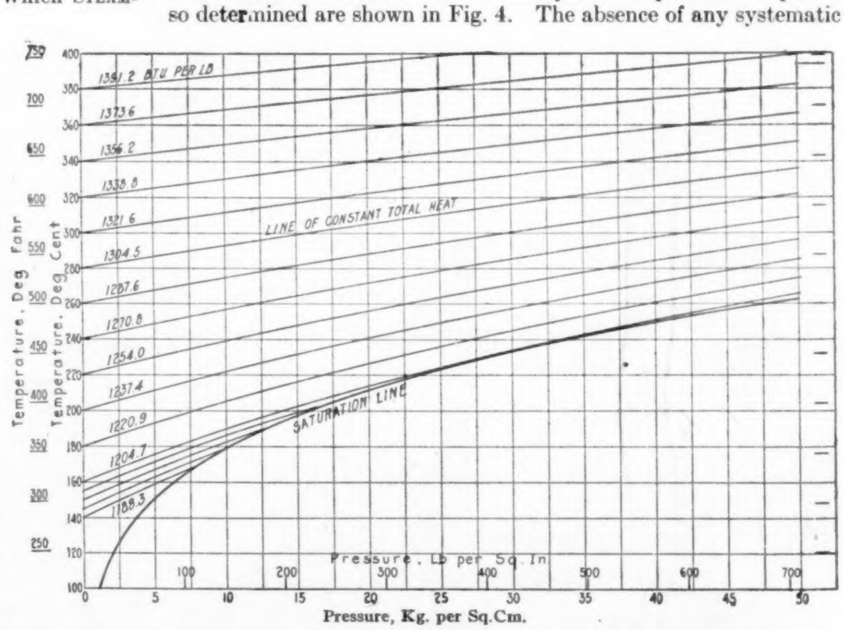


Fig. 2 Lines of Constant Total Heat Obtained by Integrating Joule-Thomson Coefficients

deviation in these points is evidence of the agreement between the Knoblauch specific heats and the Davis-Kleinschmidt Joule-Thomson coefficients.

When a mean curve through these zero-pressure specific-heat points had been decided on,[4] the specific heats for the entire superheated-steam range were determined. For use in a subsequent

[1] Presented to the A.S.M.E. Committee on Steam Research and the Extension of the Steam Tables, October 20, 1925. Reprints of this paper will shortly be available for purchase.

[2] Turbine Engineering Department, General Electric Company.

[3] H. N. Davis, Progress Report on the Joule-Thomson Effect. Mechanical Engineering, February, 1925, p. 107.

[4] H. N. Davis, Progress Reports on the Joule-Thomson Effect, Mechanical Engineering, February, 1924, p. 85, and February, 1925, p. 107.

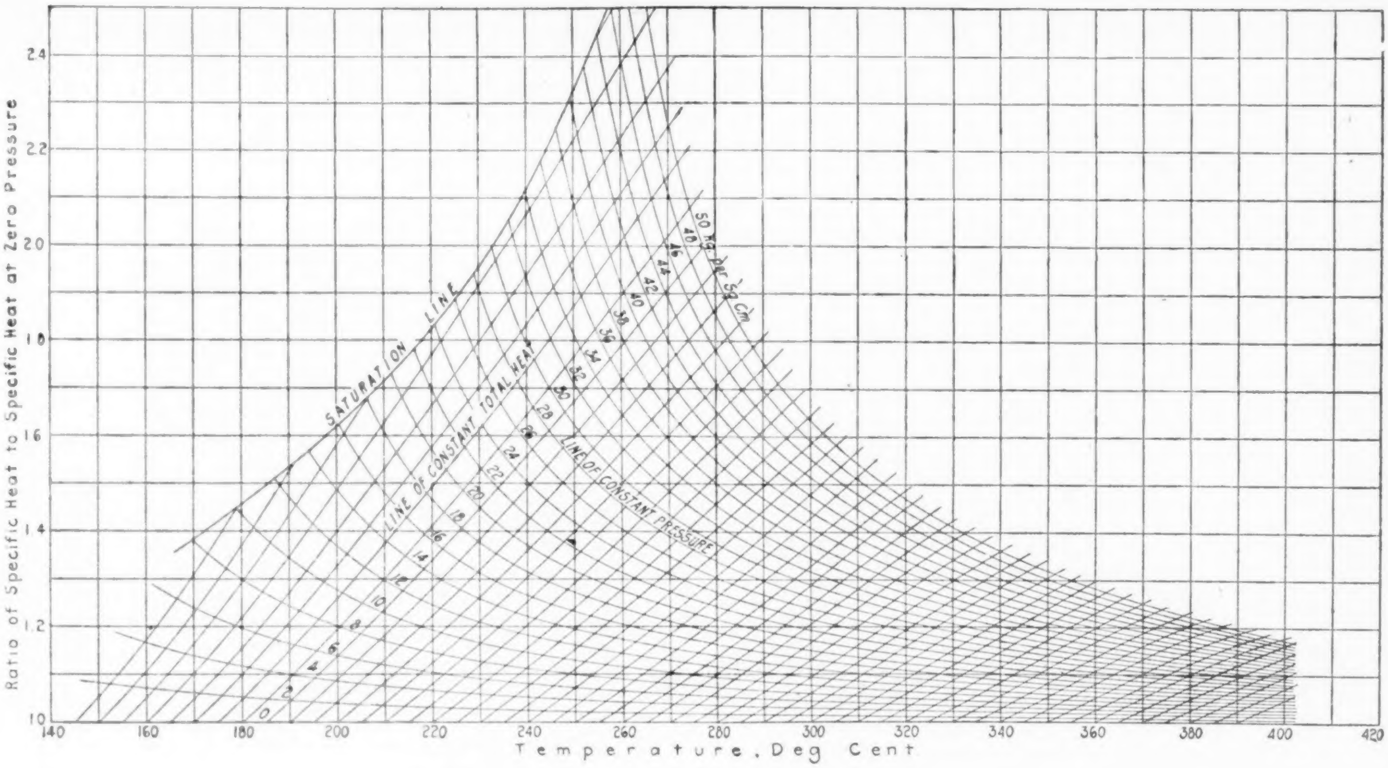


FIG. 3 RATIO OF c_p TO c_p AT ZERO PRESSURE
(The c_p at zero pressure value is taken at the same total heat as c_p.)

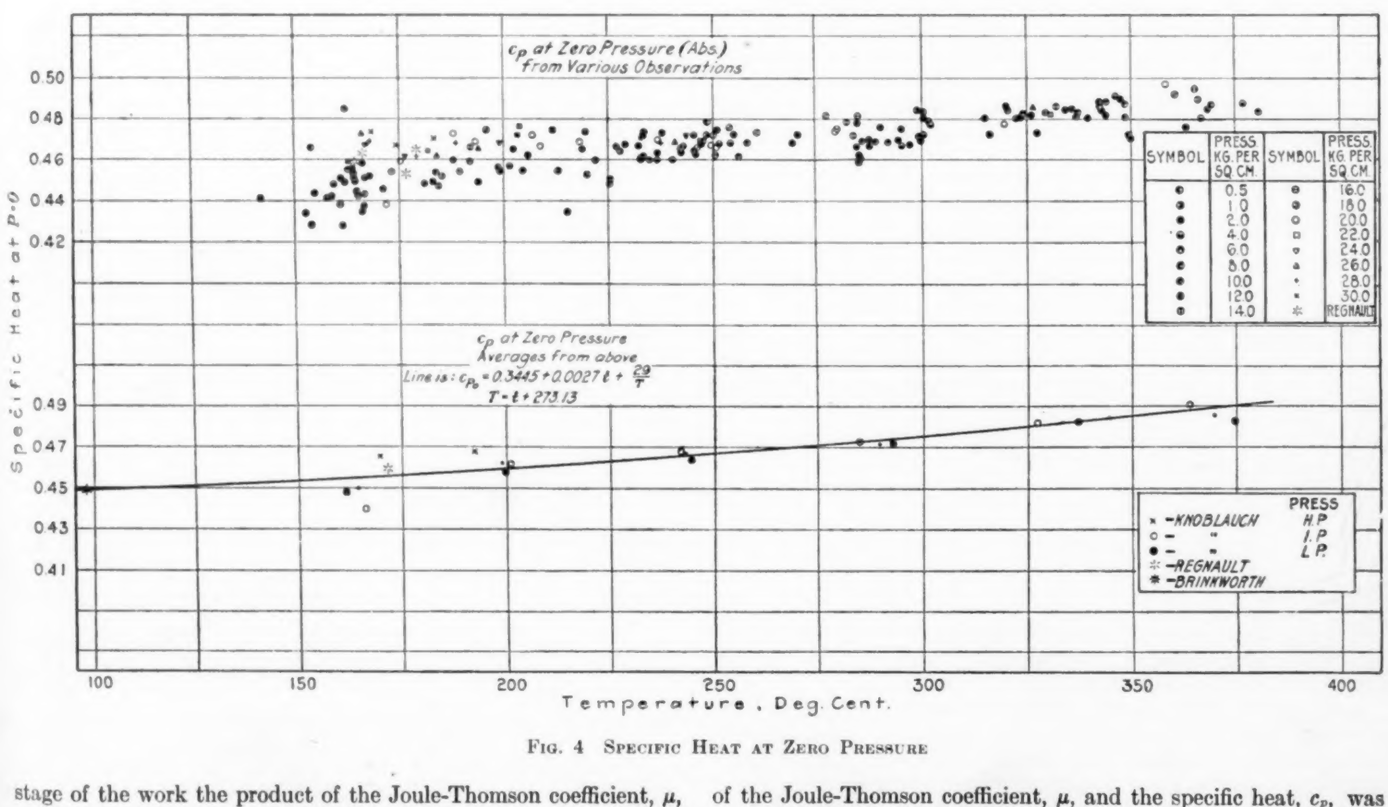


FIG. 4 SPECIFIC HEAT AT ZERO PRESSURE

stage of the work the product of the Joule-Thomson coefficient, μ, and the specific heat, c_p, was tabulated for the region investigated.

Beyond this point the work may be divided into two parts which were dealt with in different ways, namely,

1 That in the region of high superheats, and
2 That near saturation.

THE REGION OF HIGH SUPERHEATS

For the region of higher superheats a formulation of the product of the Joule-Thomson coefficient, μ, and the specific heat, c_p, was developed by Dr. Davis which fitted very exactly the values which had been tabulated. An attempt to extend this formulation to the region near saturation involved a troublesome correction term and disclosed other obstacles which, though not insuperable, were for the present better sidestepped than overcome.

The c_p formula,

$$K\mu c_p = 6.37 + \frac{A}{T^m} + \frac{Bp^{5/4}}{T^n} \dots\dots\dots\dots\dots [1]$$

where K = mechanical equivalent of heat, kg-cm. per kg-cal.
μ = Joule-Thomson coefficient, deg. cent. per kg. per sq. cm.
c_p = specific heat at constant pressure, kg-cal. per kg. per deg. cent.
p = pressure, kg. per sq. cm. abs.
T = temperature, deg. cent., abs.; $m = 4.2$; $n = 10.5$
$\log_{10}A = 12.830449$
$\log_{10}B = 27.940000$

was developed into the following expressions for the total heat, entropy, and specific volume:

$$H = H_0 + \int_{T_0}^{T} c_{p0}dT - 6.37\frac{Ap}{T^m} - \frac{4}{9}\frac{Bp^{9/4}}{T^n} \ldots\ldots [2]$$

$$\phi = \phi_0 + \int_{T_0}^{T} c_{p0}dT - R\log_e p - \frac{mAp}{(m+1)T^{m+1}} - \frac{4}{9}\frac{nBp}{(n+1)T^{n+1}} - DRp \ldots\ldots\ldots\ldots [3]$$

$$V = \frac{RT}{p} - 6.37\frac{A}{(m+1)T^m} - \frac{Bp^{5/4}}{(n+1)T^n} + DRT \ldots [4]$$

where $\log_{10} R = 0.67271$
$DR = 0.005900$
H_0, ϕ_0, T_0 = arbitrary constants.

These three expressions are obtained from Equation [1], the first and second laws of thermodynamics, and the assumption that $p(V - b)/RT$ approaches $1 + Dp$ as T approaches infinity. The reasons for making this assumption have already been published by Dr. Davis.[5] The Knoblauch, Linde, and Klebe specific-volume determinations were used to find the value of D. This automatically brought this formula into agreement with the Marks and Davis specific volumes at the lower temperatures.

Three constants of integration, H_0, ϕ_0, T_0, will be noted in the expressions for total heat and entropy. These were arbitrary constants and their choice depended solely on the data accepted in the lower temperature range not covered by the Joule-Thomson tests. The Marks and Davis tables were considered satisfactory at the lower temperatures; consequently the new charts and tables consist of the Marks and Davis values below 320 deg. fahr. and of the new development at higher temperatures. The arbitrary constants were so chosen as to bring the two sets of data into agreement at about 320 deg. fahr. saturation.

The Region Near Saturation

Equations [2], [3], and [4] were used to determine the properties of steam for superheats greater than 200 deg. fahr. But for lower superheats where the μc_p formulation was not satisfactory it was necessary to find a different method.

The constant-total-heat-line chart, Fig. 2, could be used to find the total heat at any pressure and temperature if the total heats at zero pressure were known. These could be found readily by an integration of the specific heat at zero pressure.

$$H \text{ (at } p = 0) = H_0 + \int_{T_0}^{T} c_{p0}dT$$

Having made this calculation, the total heat along each of the constant-total-heat lines (Fig. 2) was known and intermediate values could be accurately determined by interpolation.

Knowing the total heats and entropies above 200 deg. fahr. superheat and the total heats down to saturation, the additional entropy values could be obtained readily by dividing successive small finite total-heat increments along constant-pressure lines by the average absolute temperatures over the respective intervals:

$$\Delta\phi = \frac{\Delta H}{T}$$

Having done this there was at hand all the information necessary to the drafting of a Mollier diagram (Fig. 8). Much labor was saved in obtaining data for this diagram by following out a suggestion made by Prof. G. A. Goodenough. Charts of differences between the new data and the Goodenough values, shown in Figs. 5, 6, and 7, were drawn up and the entire diagram plotted from these. The smallness of the quantities involved in the difference charts greatly reduced the number of calculations necessary to cover the entire superheated-steam region.

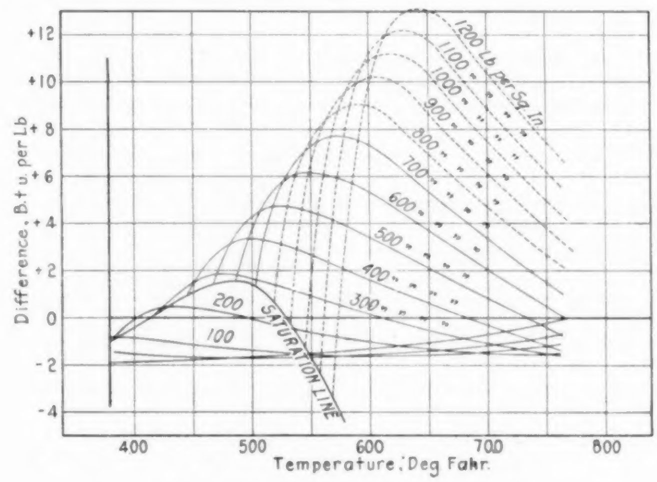


FIG. 5 TOTAL HEAT-DIFFERENCE CHART
(New chart values minus corresponding Goodenough values.)

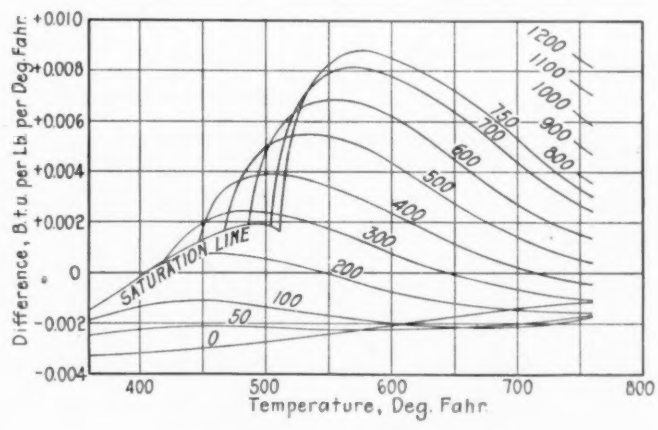


FIG. 6 ENTROPY-DIFFERENCE CHART
(New chart values minus corresponding Goodenough values. Figures on curves represent pressure in lb. per sq. in., abs.)

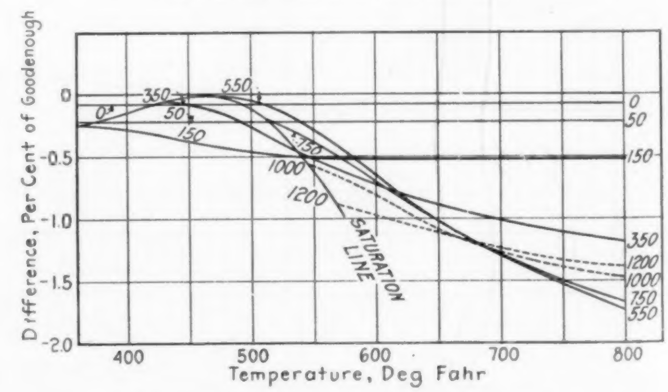
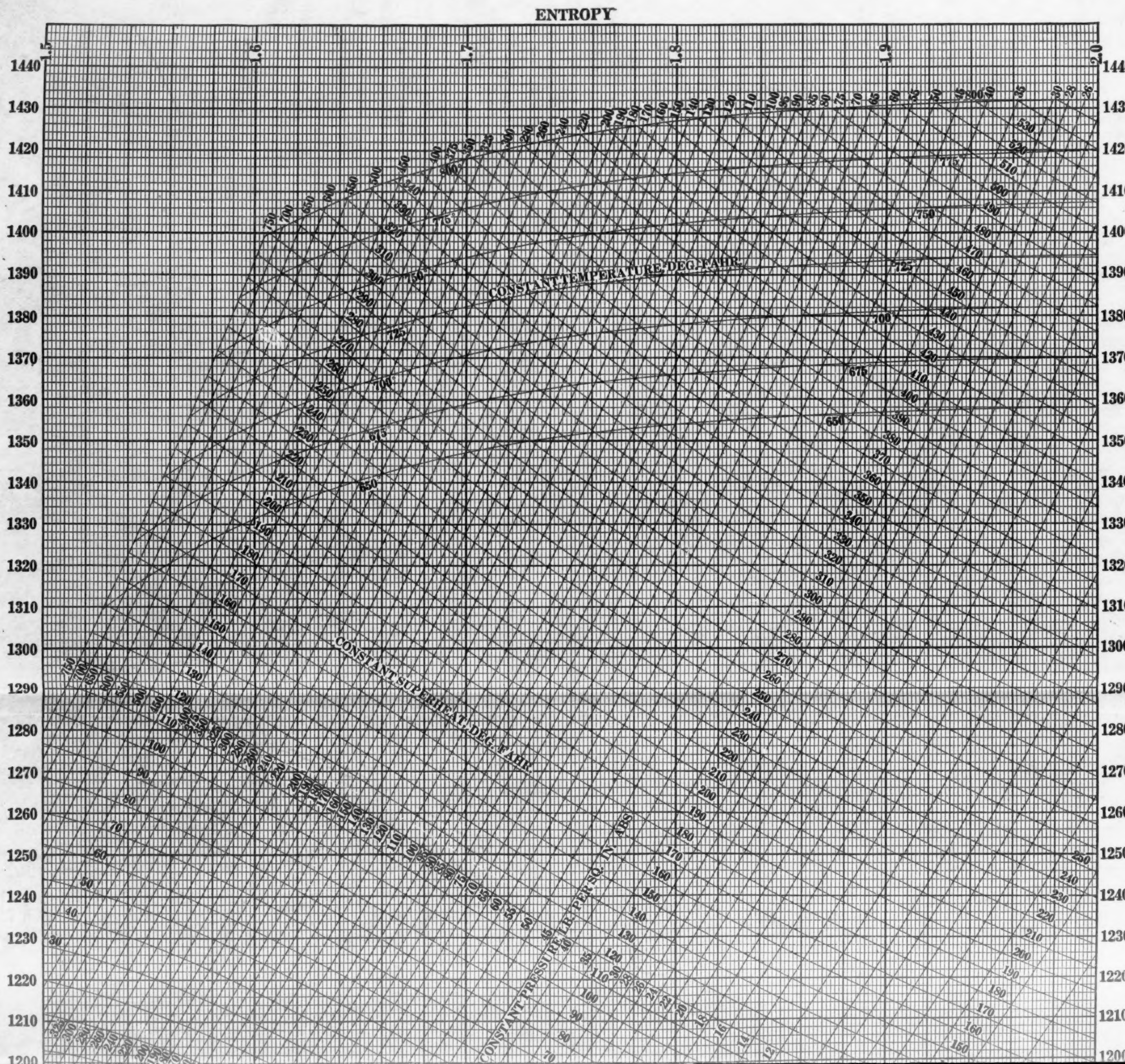


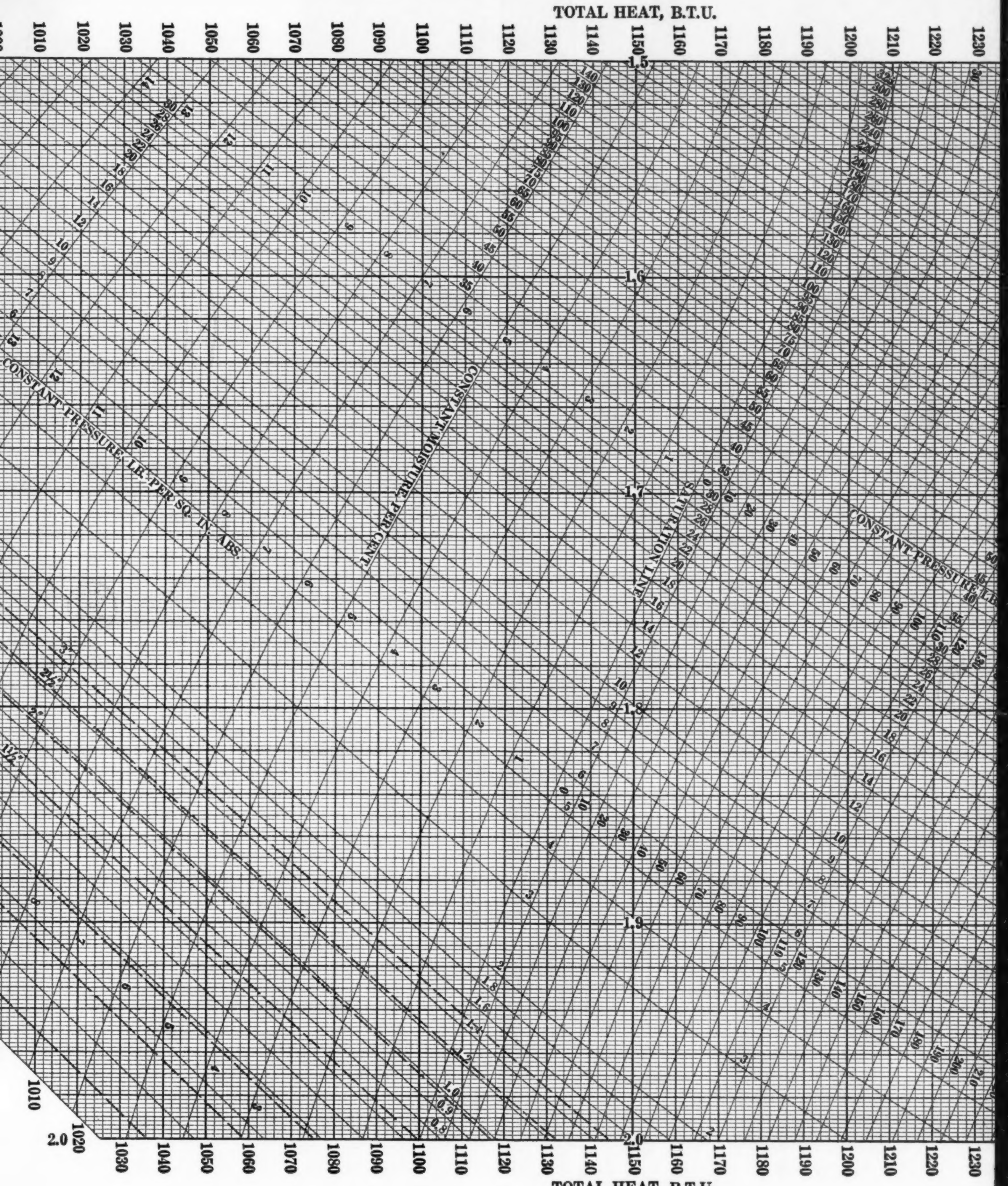
FIG. 7 SPECIFIC-VOLUME-DIFFERENCE CHART
(New values minus corresponding Goodenough values in per cent of Goodenough values. Figures on curves represent pressure in lb. per sq. in., abs.)

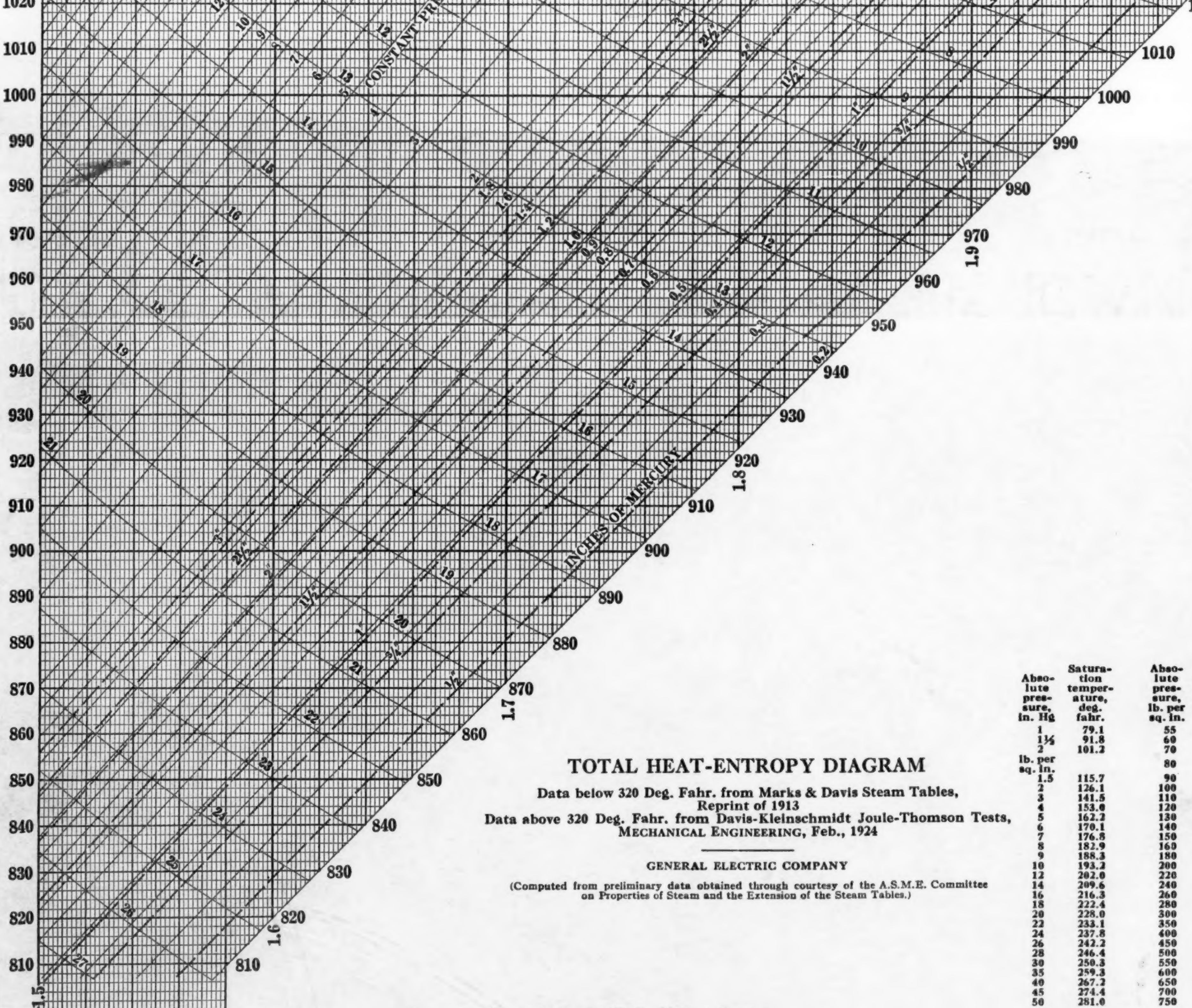
The specific volumes above 200 deg. fahr. superheat were found from Equation [4]. In order to step down from 200 deg. superheat to saturation along constant-pressure lines use was made of the relationship

$$\left(\frac{\partial V}{\partial T}\right)_p = -\left(\frac{\partial \phi}{\partial p}\right)_T \ldots\ldots\ldots\ldots [5]$$

[5] H. N. Davis, Progress Report on Joule-Thomson Effect, MECHANICAL ENGINEERING, February, 1925, p. 107.


ENTROPY
CONSTANT TEMPERATURE, DEG. FAHR.
CONSTANT SUPERHEAT, DEG. FAHR.
CONSTANT PRESSURE, LB. PER SQ. IN. ABS.


TOTAL HEAT, B.T.U.
CONSTANT PRESSURE, LB. PER SQ. IN. ABS.
CONSTANT MOISTURE, PER CENT.
SATURATION LINE
CONSTANT PRESSURE, LB.
TOTAL HEAT, B.T.U.



TOTAL HEAT-ENTROPY DIAGRAM

Data below 320 Deg. Fahr. from Marks & Davis Steam Tables, Reprint of 1913
Data above 320 Deg. Fahr. from Davis-Kleinschmidt Joule-Thomson Tests, MECHANICAL ENGINEERING, Feb., 1924

GENERAL ELECTRIC COMPANY

(Computed from preliminary data obtained through courtesy of the A.S.M.E. Committee on Properties of Steam and the Extension of the Steam Tables.)

Absolute pressure, in. Hg	Saturation temperature, deg. fahr.	Absolute pressure, lb. per sq. in.	Saturation temperature, deg. fahr.
1	79.1	55	287.1
1½	91.8	60	292.7
2	101.2	70	302.9
lb. per sq. in.		80	312.0
1.5	115.7	90	320.3
2	126.1	100	327.8
3	141.5	110	334.8
4	153.0	120	341.3
5	162.2	130	347.4
6	170.1	140	353.1
7	176.8	150	358.5
8	182.9	160	363.6
9	188.3	180	373.1
10	193.2	200	381.9
12	202.0	220	390.0
14	209.6	240	397.5
16	216.3	260	404.5
18	222.4	280	411.2
20	228.0	300	417.5
22	233.1	350	431.9
24	237.8	400	444.8
26	242.2	450	456.5
28	246.4	500	467.2
30	250.3	550	477.2
35	259.3	600	486.5
40	267.2	650	495.2
45	274.4	700	503.4
50	281.0	750	511.1

FIG. 8 750-LB. PER SQ. IN. MOLLIER DIAGRAM

Fr

Pre
lb.
sq.
al

TABLE 1 SPECIFIC VOLUMES OF SATURATED AND SUPERHEATED STEAM, CU. FT. PER LB.

Pressure, lb. per sq. in. abs.	Saturation temperature, deg. fahr.	Superheat, deg. fahr. 0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	120°	140°	160°	180°	200°	300°	400°
1	101.8	333.0	339.3	345.5	351.7	357.8	363.9	369.9	375.9	381.9	387.9	393.9	405.8	417.8	429.8	441.7	453.7	513.4	573.1
2	126.2	173.2	176.7	179.8	183.0	186.1	189.2	192.2	195.2	198.2	201.2	204.2	210.2	216.2	222.2	228.2	234.2	264.1	293.9
3	141.5	118.5	120.7	122.8	124.9	127.0	129.0	131.0	133.0	135.1	137.1	139.1	143.1	147.1	151.1	155.1	159.1	179.1	199.0
4	153.0	90.5	92.1	93.7	95.3	96.8	98.4	99.9	101.4	102.9	104.4	106.0	109.0	112.0	115.0	118.0	121.0	136.0	150.9
5	162.3	73.3	74.6	75.9	77.2	78.4	79.7	80.9	82.1	83.3	84.5	85.7	88.2	90.6	93.0	95.4	97.8	109.8	121.8
6	170.1	61.9	63.0	64.0	65.1	66.1	67.2	68.2	69.2	70.2	71.2	72.2	74.2	76.2	78.3	80.3	82.3	92.3	102.3
7	176.8	53.6	54.5	55.4	56.3	57.2	58.1	58.9	59.8	60.7	61.6	62.5	64.3	66.0	67.7	69.4	71.1	79.6	88.2
8	182.8	47.3	48.1	48.9	49.7	50.4	51.2	52.0	52.8	53.5	54.3	55.1	56.6	58.1	59.6	61.1	62.6	70.2	77.6
9	188.3	42.4	41.3	43.8	44.5	45.2	45.9	46.6	47.2	47.9	48.6	49.3	50.6	52.0	53.3	54.7	56.0	62.7	69.3
10	193.2	38.4	39.0	39.7	40.3	41.0	41.6	42.2	42.8	43.4	44.0	44.6	45.8	47.0	48.2	49.4	50.6	56.6	62.5
11	197.8	35.1	35.7	36.3	36.8	37.4	38.0	38.5	39.1	39.7	40.2	40.7	41.8	42.9	44.1	45.1	46.2	51.7	57.1
12	202.0	32.4	32.9	33.4	34.0	34.5	35.0	35.5	36.0	36.5	37.0	37.5	38.5	39.5	40.5	41.5	42.5	47.5	52.5
13	205.9	30.05	30.53	31.01	31.49	31.97	32.44	32.91	33.38	33.85	34.32	34.79	35.73	36.67	37.60	38.52	39.42	44.07	48.67
14	209.5	28.03	28.48	28.93	29.38	29.82	30.26	30.70	31.13	31.57	32.01	32.44	33.32	34.19	35.05	35.91	36.77	41.07	45.34
15	213.0	26.29	26.71	27.12	27.53	27.94	28.35	28.76	29.17	29.58	29.99	30.40	31.22	32.03	32.84	33.65	34.45	38.46	42.46
16	216.3	24.76	25.15	25.54	25.93	26.32	26.71	27.10	27.48	27.86	28.24	28.62	29.38	30.14	30.90	31.66	32.42	36.17	39.92
17	219.4	23.40	23.77	24.14	24.51	24.87	25.23	25.59	25.95	26.31	26.67	27.03	27.75	28.47	29.19	29.90	30.61	34.16	37.68
18	222.3	22.18	22.53	22.88	23.23	23.58	23.92	24.26	24.60	24.94	25.28	25.62	26.30	26.98	27.65	28.33	29.00	32.36	35.68
19	225.2	21.08	21.42	21.75	22.08	22.41	22.74	23.07	23.39	23.71	24.03	24.35	24.99	25.64	26.28	26.92	27.56	30.74	33.90
20	228.0	20.09	20.41	20.73	21.04	21.35	21.66	21.97	22.28	22.59	22.90	23.21	23.83	24.44	25.04	25.65	26.26	29.28	32.28
21	230.6	19.19	19.50	19.81	20.11	20.41	20.71	21.01	21.30	21.60	21.89	22.18	22.76	23.34	23.93	24.51	25.08	27.96	30.82
22	233.1	18.37	18.67	18.96	19.25	19.54	19.83	20.11	20.39	20.67	20.95	21.23	21.79	22.35	22.90	23.45	24.00	26.75	29.48
23	235.5	17.62	17.90	18.18	18.46	18.74	19.01	19.28	19.55	19.82	20.09	20.36	20.89	21.43	21.96	22.49	23.02	25.64	28.25
24	237.8	16.93	17.20	17.47	17.74	18.00	18.26	18.52	18.78	19.04	19.30	19.56	20.07	20.59	21.10	21.60	22.11	24.63	27.12
25	240.1	16.30	16.56	16.82	17.07	17.32	17.57	17.82	18.07	18.32	18.57	18.82	19.32	19.81	20.30	20.79	21.28	23.70	26.10
26	242.3	15.72	15.97	16.22	16.46	16.70	16.94	17.18	17.42	17.66	17.90	18.14	18.62	19.10	19.57	20.04	20.51	22.82	25.15
27	244.4	15.18	15.42	15.66	15.89	16.12	16.35	16.59	16.81	17.04	17.27	17.50	17.97	18.44	18.88	19.33	19.79	22.01	24.26
28	246.4	14.67	14.90	15.13	15.36	15.58	15.80	16.02	16.24	16.46	16.69	16.91	17.36	17.81	18.24	18.67	19.11	21.26	23.43
29	248.4	14.19	14.42	14.64	14.86	15.08	15.29	15.51	15.72	15.93	16.15	16.36	16.79	17.22	17.64	18.06	18.48	20.57	22.66
30	250.3	13.74	13.96	14.18	14.39	14.60	14.81	15.02	15.23	15.44	15.65	15.85	16.26	16.67	17.08	17.49	17.90	19.93	21.94
31	252.2	13.32	13.54	13.75	13.96	14.17	14.37	14.58	14.78	14.98	15.18	15.37	15.77	16.16	16.57	16.96	17.36	19.33	21.26
32	254.1	12.93	13.14	13.34	13.54	13.75	13.94	14.14	14.34	14.54	14.74	14.92	15.31	15.68	16.08	16.46	16.85	18.76	20.62
33	255.9	12.57	12.77	12.97	13.16	13.36	13.55	13.74	13.93	14.12	14.32	14.50	14.88	15.23	15.62	15.99	16.37	18.22	20.02
34	257.6	12.22	12.42	12.61	12.80	12.99	13.18	13.37	13.55	13.73	13.92	14.10	14.47	14.82	15.19	15.55	15.91	17.71	19.46
35	259.3	11.89	12.08	12.27	12.46	12.64	12.82	13.01	13.18	13.36	13.54	13.72	14.08	14.43	14.79	15.14	15.48	17.23	18.94
36	261.0	11.58	11.77	11.95	12.14	12.31	12.49	12.67	12.84	13.01	13.18	13.36	13.71	14.06	14.41	14.75	15.08	16.78	18.45
37	262.6	11.29	11.47	11.65	11.83	12.00	12.17	12.34	12.51	12.68	12.84	13.02	13.36	13.70	14.04	14.38	14.70	16.35	17.98
38	264.2	11.01	11.18	11.35	11.53	11.69	11.86	12.03	12.20	12.36	12.52	12.70	13.03	13.36	13.69	14.02	14.34	15.94	17.53
39	265.8	10.74	10.91	11.08	11.25	11.41	11.57	11.73	11.89	12.06	12.22	12.39	12.72	13.04	13.36	13.68	13.99	15.55	17.10
40	267.3	10.49	10.66	10.82	10.98	11.14	11.30	11.46	11.62	11.78	11.94	12.10	12.42	12.73	13.05	13.36	13.66	15.18	16.69
41	268.7	10.25	10.41	10.57	10.73	10.89	11.05	11.21	11.37	11.52	11.68	11.83	12.14	12.43	12.76	13.05	13.34	14.82	16.30
42	270.2	10.02	10.18	10.34	10.50	10.66	10.81	10.96	11.11	11.27	11.42	11.57	11.87	12.15	12.48	12.75	13.03	14.48	15.93
43	271.7	9.80	9.96	10.12	10.27	10.42	10.57	10.72	10.87	11.02	11.17	11.32	11.61	11.89	12.21	12.47	12.74	14.16	15.58
44	273.1	9.59	9.74	9.89	10.06	10.20	10.34	10.49	10.63	10.78	10.93	11.08	11.36	11.64	11.94	12.20	12.47	13.86	15.24
45	274.5	9.39	9.54	9.69	9.84	9.99	10.13	10.27	10.41	10.55	10.70	10.84	11.12	11.40	11.68	11.95	12.21	13.57	14.92
46	275.8	9.20	9.35	9.50	9.64	9.78	9.92	10.06	10.20	10.33	10.48	10.61	10.89	11.17	11.43	11.71	11.96	13.30	14.61
47	277.2	9.02	9.16	9.30	9.44	9.58	9.72	9.86	9.99	10.12	10.27	10.40	10.66	10.94	11.19	11.47	11.72	13.04	14.32
48	278.5	8.84	8.98	9.12	9.25	9.39	9.53	9.66	9.79	9.92	10.07	10.19	10.45	10.72	10.97	11.24	11.49	12.78	14.04
49	279.8	8.67	8.81	8.94	9.07	9.20	9.34	9.47	9.60	9.73	9.87	9.99	10.25	10.51	10.76	11.02	11.27	12.53	13.77
50	281.0	8.51	8.65	8.77	8.89	9.03	9.16	9.29	9.42	9.55	9.68	9.80	10.06	10.31	10.56	10.81	11.06	12.29	13.51
51	282.3	8.35	8.49	8.61	8.73	8.86	8.99	9.12	9.25	9.38	9.50	9.62	9.88	10.12	10.37	10.61	10.85	12.06	13.26
52	283.5	8.20	8.34	8.46	8.57	8.70	8.83	8.96	9.08	9.21	9.33	9.45	9.70	9.94	10.18	10.42	10.65	11.84	13.02
53	284.7	8.05	8.19	8.31	8.42	8.55	8.67	8.80	8.92	9.05	9.17	9.29	9.53	9.76	10.00	10.24	10.46	11.63	12.79
54	285.9	7.91	8.04	8.17	8.28	8.40	8.52	8.65	8.77	8.89	9.01	9.13	9.37	9.59	9.83	10.06	10.28	11.43	12.57
55	287.1	7.78	7.91	8.03	8.14	8.26	8.38	8.50	8.62	8.74	8.86	8.98	9.21	9.43	9.66	9.89	10.11	11.24	12.35
56	288.2	7.65	7.78	7.89	8.00	8.12	8.24	8.36	8.48	8.60	8.72	8.83	9.06	9.27	9.50	9.73	9.95	11.06	12.14
57	289.4	7.52	7.65	7.76	7.87	7.99	8.11	8.23	8.34	8.46	8.58	8.68	8.91	9.12	9.34	9.57	9.79	10.88	11.94
58	290.5	7.40	7.52	7.63	7.74	7.86	7.98	8.10	8.21	8.32	8.44	8.54	8.77	8.97	9.19	9.42	9.63	10.70	11.75
59	291.6	7.28	7.40	7.51	7.62	7.74	7.85	7.97	8.08	8.19	8.30	8.40	8.63	8.83	9.05	9.27	9.48	10.53	11.56
60	292.7	7.16	7.28	7.39	7.50	7.62	7.73	7.84	7.95	8.06	8.17	8.27	8.49	8.70	8.91	9.12	9.33	10.36	11.38
61	293.8	7.05	7.16	7.28	7.38	7.50	7.61	7.72	7.83	7.94	8.04	8.14	8.36	8.57	8.77	8.98	9.19	10.19	11.20
62	294.9	6.95	7.05	7.17	7.27	7.39	7.50	7.60	7.71	7.82	7.91	8.02	8.23	8.44	8.64	8.84	9.05	10.03	11.02
63	295.9	6.84	6.95	7.06	7.16	7.28	7.39	7.49	7.59	7.70	7.79	7.90	8.11	8.31	8.51	8.71	8.91	9.88	10.85
64	297.0	6.74	6.84	6.95	7.06	7.17	7.28	7.38	7.48	7.58	7.68	7.78	7.99	8.19	8.39	8.58	8.78	9.73	10.69
65	298.0	6.64	6.75	6.85	6.96	7.06	7.17	7.27	7.37	7.47	7.57	7.67	7.87	8.07	8.27	8.46	8.65	9.59	10.53
66	299.0	6.55	6.66	6.75	6.86	6.96	7.07	7.16	7.26	7.37	7.47	7.56	7.76	7.95	8.15	8.34	8.53	9.45	10.38
67	300.0	6.46	6.56	6.66	6.76	6.86	6.97	7.06	7.16	7.27	7.37	7.46	7.65	7.84	8.04	8.22	8.41	9.32	10.23
68	301.0	6.37	6.47	6.57	6.67	6.77	6.87	6.96	7.06	7.17	7.27	7.36	7.54	7.73	7.93	8.11	8.29	9.19	10.09
69	302.0	6.28	6.39	6.48	6.58	6.68	6.78	6.87	6.97	7.07	7.17	7.26	7.44	7.63	7.82	8.00	8.18	9.06	9.95
70	302.9	6.20	6.30	6.39	6.49	6.59	6.69	6.78	6.88	6.97	7.07	7.16	7.34	7.53	7.71	7.89	8.07	8.94	9.82
71	303.9	6.11	6.22	6.31	6.40	6.50	6.60	6.69	6.79	6.88	6.98	7.07	7.25	7.43	7.61	7.79	7.97	8.83	9.69
72	304.8	6.03	6.13	6.23	6.31	6.42	6.51	6.60	6.70	6.79	6.89	6.98	7.16	7.33	7.51	7.69	7.87	8.72	9.56
73	305.8	5.95	6.05	6.15	6.23	6.34	6.43	6.52	6.61	6.70	6.80	6.89	7.07	7.24	7.41	7.59	7.77	8.61	9.44
74	306.7	5.88	5.97	6.07	6.15	6.26	6.35	6.44	6.53	6.61	6.71	6.80	6.98	7.15	7.32	7.49	7.67	8.50	9.32
75	307.6	5.80	5.90	5.99	6.08	6.18	6.27	6.36	6.45	6.53	6.62	6.71	6.89	7.06	7.23	7.40	7.57	8.40	9.20
76	308.5	5.73	5.83	5.92	6.01	6.10	6.19	6.28	6.37	6.45	6.54	6.63	6.80	6.97	7.14	7.31	7.47	8.29	9.09
77	309.4	5.66	5.76	5.85	5.94	6.03	6.11	6.20	6.29	6.37	6.46	6.55	6.72	6.88	7.05	7.22	7.38	8.19	8.98
78	310.3	5.59	5.69	5.78	5.87	5.96	6.04	6.12	6.21	6.29	6.38	6.47	6.64	6.80	6.96	7.13	7.29	8.09	8.87
79	311.2	5.53	5.62	5.71	5.80	5.89	5.97	6.05	6.14	6.22	6.30	6.39	6.56	6.72	6.88	7.04	7.20	7.99	8.76
80	312.0	5.46	5.55	5.64	5.73	5.82	5.90	5.98	6.07	6.15	6.23	6.32	6.48	6.64	6.80	6.96	7.11	7.89	8.66
81	312.9	5.40	5.48	5.57	5.66	5.75	5.83	5.91	6.00	6.08	6.16	6.24	6.40	6.56	6.72	6.88	7.03	7.80	8.56
82	313.8	5.33	5.42	5.50	5.59	5.68	5.76	5.84	5.93	6.01	6.09	6.17	6.33	6.48	6.64	6.80	6.95	7.71	8.46
83	314.6	5.27	5.36	5.44	5.52	5.61	5.69	5.77	5.86	5.94	6.02	6.10	6.26	6.41	6.56	6.72	6.87	7.62	8.36
84	315.4	5.21	5.30	5.38	5.46	5.55	5.63	5.71	5.79	5.87	5.95	6.03	6.19	6.34	6.49	6.64	6.79	7.54	8.27
85	316.3	5.16	5.24	5.32	5.40	5.49	5.57	5.65	5.73	5.81	5.88	5.96	6.12	6.27	6.42	6.57	6.72	7.46	8.18
86	317.1	5.10	5.18	5.26	5.34	5.43	5.51	5.59	5.67	5.75	5.82	5.90	6.05	6.20	6.35	6.50	6.64	7.38	8.09
87	317.9	5.04	5.13	5.20	5.28	5.37	5.45	5.53	5.61	5.69	5.76	5.84	5.98	6.13	6.28	6.43	6.57	7.30	8.00
88	318.7	4.99	5.07	5.15	5.23	5.31	5.39	5.47	5.55	5.63	5.70	5.78	5.91	6.06	6.21	6.36	6.50	7.22	7.91
89	319.5	4.94	5.02	5.10	5.18	5.26	5.33	5.41	5.49	5.57	5.64	5.72	5.85	6.00	6.14	6.29	6.43	7.14	7.83
90	320.3	4.89	4.97	5.05	5.13	5.21	5.28	5.36	5.44	5.51	5.58	5.66	5.79	5.94	6.08	6.22	6.36	7.07	7.75
91	321.1	4.84	4.921	5.00	5.08	5.15	5.22	5.30	5.38	5.45	5.52	5.60	5.73	5.88	6.02	6.16	6.30	7.00	7.67
92	321.8	4.791	4.873	4.95	5.03	5.10	5.17	5.25	5.32	5.39	5.46	5.54	5.67	5.82	5.96	6.10	6.24	6.93	7.59
93	322.6	4.742	4.825	4.90	4.98	5.05	5.12	5.20	5.27	5.33	5.40	5.48	5.61	5.76	5.90	6.04	6.18	6.86	7.51
94	323.4	4.695	4.777	4.85	4.93	5.00	5.07	5.15	5.22	5.28	5.35	5.42	5.56	5.70	5.84	5.98	6.12	6.79	7.43
95	324.1	4.649	4.73	4.80	4.88	4.95	5.02	5.10	5.17	5.23	5.30	5.37	5.51	5.65	5.78	5.92	6.06	6.72	7.35
96	324.9	4.603	4.683	4.752	4.829	4.899	4.970	5.047	5.118	5.176	5.25	5.31	5.45	5.59	5.72	5.86	6.00	6.65	7.28
97	325.6	4.558	4.636	4.705	4.779	4.849	4.921	4.996	5.067	5.124	5.20	5.26	5.40	5.53	5.66	5.80	5.94	6.58	7.21
98	326.4	4.514	4.590	4.659	4.731	4.801	4.873	4.946	5.017	5.074	5.15	5.21	5.35	5.48	5.61	5.74	5.88	6.51	7.14
99	327.1	4.471	4.545	4.614	4.685	4.755	4.826	4.897	4.968	5.026	5.10	5.16	5.30	5.43	5.56	5.69	5.82	6.44	7.07
100	327.8	4.429	4.50	4.57	4.64	4.71	4.78	4.85	4.92	4.98	5.05	5.11	5.25	5.38	5.51	5.64	5.77	6.38	7.00
101	328.6	4.387	4.457	4.528	4.597	4.666	4.735	4.804	4.872	4.937	5.003	5.066	5.200	5.331	5.457	5.586	5.713	6.32	6.93
102	329.3	4.346	4.415	4.487	4.556	4.622	4.691	4.760	4.825	4.894	4.957	5.022	5.152	5.283	5.405	5.533	5.658	6.27	6.86
103	330.0	4.305	4.374	4.446	4.515	4.579	4.648	4.717	4.780	4.851	4.912	4.979	5.105	5.236	5.355	5.482	5.605	6.22	6.80
104	330.7	4.266	4.334	4.406	4.475	4.537	4.606	4.675	4.736	4.808	4.868	4.936	5.059	5.189	5.307	5.433	5.553	6.16	6.74
105	331.4	4.227	4.296	4.366	4.435	4.496	4.565	4.634	4.694	4.765	4.825	4.893	5.014	5.143	5.260	5.385	5.503	6.11	6.68

TABLE 1 SPECIFIC VOLUMES OF SATURATED AND SUPERHEATED STEAM, CU. FT. PER LB. (*Continued*)

Pressure, lb. per sq. in. abs.	Saturation temperature, deg. fahr.	Superheat, deg. fahr. 0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	120°	140°	160°	180°	200°	300°	400°
106	332.0	4.189	4.258	4.326	4.394	4.456	4.525	4.593	4.654	4.722	4.782	4.850	4.970	5.097	5.214	5.338	5.455	6.05	6.62
107	332.7	4.153	4.220	4.287	4.354	4.417	4.485	4.553	4.614	4.679	4.740	4.807	4.927	5.052	5.169	5.291	5.408	6.00	6.56
108	333.4	4.116	4.183	4.249	4.315	4.378	4.446	4.513	4.574	4.636	4.698	4.765	4.885	5.008	5.125	5.245	5.362	5.95	6.51
109	334.1	4.080	4.146	4.212	4.277	4.340	4.408	4.473	4.534	4.594	4.658	4.724	4.844	4.965	5.081	5.200	5.316	5.90	6.45
110	334.8	4.045	4.110	4.176	4.240	4.303	4.370	4.433	4.495	4.554	4.619	4.684	4.803	4.923	5.038	5.155	5.271	5.85	6.40
111	335.4	4.010	4.074	4.141	4.204	4.267	4.332	4.393	4.455	4.516	4.581	4.645	4.762	4.882	4.995	5.111	5.226	5.80	6.34
112	336.1	3.976	4.038	4.106	4.169	4.231	4.294	4.354	4.415	4.479	4.544	4.607	4.721	4.842	4.952	5.067	5.182	5.75	6.29
113	336.8	3.942	4.003	4.072	4.134	4.195	4.257	4.316	4.376	4.443	4.507	4.569	4.681	4.802	4.910	5.024	5.138	5.70	6.24
114	337.4	3.909	3.969	4.039	4.100	4.160	4.221	4.280	4.339	4.409	4.471	4.532	4.642	4.763	4.869	4.982	5.095	5.66	6.19
115	338.1	3.877	3.936	4.006	4.066	4.126	4.186	4.245	4.305	4.375	4.435	4.495	4.604	4.724	4.829	4.941	5.053	5.61	6.14
116	338.7	3.845	3.904	3.973	4.033	4.093	4.152	4.212	4.273	4.341	4.399	4.458	4.567	4.685	4.790	4.901	5.012	5.56	6.09
117	339.4	3.815	3.874	3.940	4.000	4.061	4.119	4.180	4.241	4.307	4.363	4.421	4.531	4.647	4.751	4.862	4.972	5.51	6.04
118	340.0	3.784	3.845	3.908	3.968	4.029	4.088	4.148	4.209	4.273	4.327	4.385	4.495	4.609	4.713	4.824	4.933	5.46	5.99
119	340.6	3.754	3.816	3.877	3.937	3.998	4.057	4.117	4.177	4.239	4.291	4.350	4.460	4.572	4.676	4.787	4.895	5.42	5.94
120	341.3	3.724	3.787	3.847	3.907	3.967	4.026	4.086	4.145	4.206	4.256	4.316	4.425	4.535	4.640	4.750	4.857	5.38	5.90
121	341.9	3.694	3.758	3.818	3.878	3.936	3.995	4.055	4.113	4.173	4.222	4.282	4.391	4.498	4.605	4.712	4.819	5.34	5.85
122	342.5	3.665	3.729	3.789	3.849	3.905	3.964	4.024	4.081	4.140	4.188	4.249	4.357	4.462	4.507	4.675	4.781	5.30	5.81
123	343.2	3.637	3.701	3.761	3.821	3.874	3.934	3.994	4.049	4.108	4.155	4.216	4.323	4.426	4.535	4.638	4.744	5.26	5.77
124	343.8	3.609	3.673	3.733	3.793	3.844	3.904	3.964	4.017	4.076	4.123	4.184	4.290	4.391	4.500	4.602	4.708	5.22	5.72
125	344.4	3.582	3.645	3.705	3.765	3.815	3.875	3.934	3.985	4.044	4.092	4.152	4.257	4.357	4.466	4.568	4.673	5.18	5.68
126	345.0	3.555	3.618	3.678	3.737	3.788	3.846	3.904	3.953	4.013	4.062	4.120	4.225	4.324	4.432	4.535	4.639	5.14	5.63
127	345.6	3.528	3.591	3.651	3.708	3.761	3.817	3.874	3.922	3.983	4.032	4.088	4.194	4.292	4.398	4.503	4.606	5.11	5.59
128	346.2	3.502	3.564	3.624	3.679	3.735	3.789	3.844	3.892	3.953	4.003	4.056	4.163	4.261	4.365	4.471	4.573	5.07	5.55
129	346.8	3.477	3.537	3.597	3.651	3.709	3.761	3.815	3.863	3.924	3.974	4.025	4.132	4.230	4.332	4.440	4.541	5.04	5.51
130	347.4	3.451	3.510	3.571	3.623	3.683	3.733	3.786	3.836	3.896	3.946	3.995	4.101	4.200	4.300	4.409	4.509	5.00	5.47
131	348.0	3.426	3.484	3.545	3.595	3.656	3.705	3.757	3.811	3.868	3.918	3.967	4.070	4.170	4.269	4.378	4.477	4.96	5.43
132	348.5	3.402	3.458	3.519	3.568	3.630	3.678	3.728	3.786	3.841	3.891	3.940	4.040	4.141	4.240	4.347	4.445	4.93	5.39
133	349.1	3.377	3.432	3.493	3.542	3.604	3.652	3.701	3.761	3.814	3.864	3.913	4.011	4.112	4.212	4.316	4.413	4.89	5.35
134	349.7	3.353	3.407	3.467	3.517	3.578	3.627	3.675	3.736	3.787	3.837	3.887	3.983	4.084	4.184	4.285	4.381	4.85	5.32
135	350.3	3.330	3.382	3.442	3.492	3.552	3.602	3.651	3.711	3.761	3.811	3.861	3.956	4.056	4.156	4.255	4.350	4.82	5.28
136	350.8	3.306	3.358	3.418	3.468	3.526	3.578	3.628	3.686	3.736	3.786	3.835	3.931	4.028	4.128	4.224	4.320	4.78	5.24
137	351.4	3.283	3.334	3.395	3.444	3.501	3.555	3.605	3.661	3.711	3.761	3.809	3.906	4.001	4.100	4.193	4.290	4.74	5.20
138	352.0	3.260	3.311	3.372	3.421	3.476	3.532	3.582	3.636	3.686	3.736	3.783	3.881	3.974	4.072	4.163	4.261	4.71	5.17
139	352.5	3.238	3.288	3.349	3.398	3.452	3.509	3.559	3.611	3.661	3.711	3.757	3.856	3.947	4.044	4.134	4.233	4.68	5.13
140	353.1	3.216	3.266	3.326	3.376	3.429	3.486	3.536	3.586	3.636	3.686	3.731	3.831	3.921	4.016	4.106	4.205	4.65	5.10
141	353.6	3.194	3.244	3.303	3.354	3.407	3.463	3.512	3.562	3.611	3.660	3.705	3.805	3.895	3.988	4.079	4.177	4.62	5.07
142	354.2	3.172	3.222	3.281	3.332	3.385	3.440	3.488	3.538	3.586	3.634	3.679	3.780	3.869	3.960	4.052	4.150	4.59	5.03
143	354.7	3.152	3.200	3.259	3.311	3.363	3.416	3.465	3.515	3.561	3.609	3.654	3.755	3.844	3.933	4.025	4.123	4.57	5.00
144	355.3	3.131	3.179	3.237	3.290	3.341	3.392	3.442	3.492	3.537	3.584	3.629	3.730	3.819	3.906	3.999	4.096	4.54	4.97
145	355.8	3.111	3.159	3.215	3.269	3.319	3.369	3.419	3.469	3.513	3.559	3.605	3.705	3.794	3.880	3.973	4.069	4.51	4.94
146	356.3	3.090	3.140	3.193	3.247	3.297	3.347	3.397	3.447	3.490	3.535	3.582	3.681	3.768	3.854	3.947	4.042	4.48	4.91
147	356.9	3.070	3.121	3.172	3.226	3.275	3.326	3.375	3.425	3.467	3.512	3.559	3.657	3.743	3.828	3.921	4.015	4.45	4.88
148	357.4	3.050	3.102	3.152	3.205	3.254	3.305	3.354	3.404	3.445	3.490	3.537	3.634	3.718	3.803	3.895	3.988	4.42	4.85
149	357.9	3.030	3.083	3.132	3.184	3.233	3.284	3.333	3.383	3.423	3.468	3.515	3.611	3.693	3.779	3.870	3.962	4.40	4.82
150	358.5	3.011	3.064	3.113	3.163	3.213	3.263	3.313	3.362	3.402	3.447	3.493	3.588	3.669	3.755	3.845	3.936	4.37	4.79
152	359.5	2.975	3.026	3.075	3.125	3.174	3.223	3.273	3.320	3.360	3.403	3.448	3.542	3.625	3.708	3.795	3.886	4.31	4.73
154	360.5	2.939	2.988	3.037	3.088	3.135	3.183	3.234	3.279	3.319	3.361	3.404	3.497	3.582	3.663	3.746	3.838	4.25	4.67
156	361.6	2.903	2.951	3.000	3.051	3.096	3.144	3.195	3.238	3.279	3.320	3.361	3.454	3.540	3.619	3.700	3.792	4.20	4.61
158	362.6	2.868	2.915	2.964	3.015	3.057	3.106	3.157	3.198	3.240	3.280	3.320	3.412	3.498	3.577	3.657	3.748	4.15	4.55
160	363.6	2.833	2.880	2.929	2.979	3.019	3.069	3.119	3.159	3.201	3.241	3.281	3.371	3.457	3.537	3.616	3.706	4.10	4.50
162	364.6	2.800	2.847	2.894	2.944	2.982	3.033	3.081	3.121	3.163	3.204	3.244	3.331	3.417	3.499	3.577	3.666	4.05	4.45
164	365.6	2.767	2.814	2.859	2.909	2.947	2.998	3.044	3.084	3.126	3.167	3.207	3.292	3.378	3.461	3.539	3.626	4.01	4.40
166	366.5	2.746	2.782	2.825	2.875	2.913	2.964	3.008	3.048	3.090	3.131	3.171	3.254	3.340	3.423	3.501	3.586	3.97	4.35
168	367.5	2.705	2.751	2.792	2.842	2.881	2.931	2.973	3.013	3.056	3.096	3.136	3.217	3.303	3.385	3.464	3.546	3.92	4.31
170	368.5	2.674	2.720	2.760	2.810	2.850	2.899	2.939	2.979	3.022	3.062	3.102	3.181	3.267	3.347	3.427	3.507	3.88	4.26
172	369.4	2.644	2.689	2.729	2.778	2.820	2.867	2.906	2.946	2.988	3.028	3.069	3.147	3.231	3.309	3.390	3.467	3.83	4.21
174	370.4	2.615	2.659	2.699	2.747	2.791	2.836	2.894	2.914	2.954	2.994	3.036	3.114	3.196	3.272	3.354	3.427	3.79	4.16
176	371.3	2.586	2.630	2.670	2.717	2.762	2.805	2.843	2.883	2.922	2.961	3.004	3.082	3.162	3.236	3.318	3.388	3.75	4.12
178	372.2	2.558	2.602	2.642	2.687	2.733	2.774	2.813	2.852	2.891	2.930	2.972	3.051	3.129	3.200	3.282	3.350	3.71	4.07
180	373.1	2.531	2.574	2.614	2.658	2.704	2.744	2.784	2.822	2.861	2.900	2.940	3.020	3.097	3.166	3.246	3.313	3.67	4.03
182	374.0	2.504	2.547	2.587	2.630	2.675	2.715	2.755	2.792	2.832	2.871	2.908	2.989	3.066	3.134	3.211	3.277	3.63	3.98
184	374.9	2.478	2.521	2.561	2.602	2.646	2.686	2.726	2.763	2.803	2.843	2.877	2.958	3.035	3.103	3.178	3.243	3.60	3.94
186	375.8	2.452	2.495	2.535	2.575	2.618	2.658	2.697	2.735	2.775	2.815	2.847	2.927	3.005	3.073	3.146	3.211	3.56	3.90
188	376.7	2.427	2.469	2.509	2.549	2.590	2.630	2.669	2.708	2.747	2.787	2.819	2.897	2.975	3.044	3.115	3.180	3.52	3.86
190	377.6	2.403	2.443	2.483	2.523	2.563	2.603	2.642	2.682	2.719	2.759	2.792	2.868	2.945	3.015	3.085	3.150	3.49	3.82
192	378.5	2.378	2.417	2.457	2.497	2.537	2.577	2.616	2.657	2.691	2.731	2.767	2.840	2.915	2.986	3.056	3.120	3.45	3.78
194	379.3	2.355	2.392	2.432	2.471	2.512	2.552	2.591	2.632	2.664	2.704	2.742	2.812	2.886	2.957	3.027	3.089	3.41	3.74
196	380.2	2.332	2.367	2.407	2.446	2.488	2.528	2.567	2.608	2.638	2.678	2.717	2.785	2.858	2.929	2.998	3.059	3.38	3.70
198	381.0	2.309	2.343	2.383	2.422	2.464	2.504	2.543	2.584	2.612	2.652	2.692	2.759	2.830	2.901	2.969	3.029	3.35	3.66
200	381.9	2.287	2.320	2.360	2.400	2.440	2.480	2.520	2.560	2.587	2.627	2.667	2.733	2.803	2.873	2.940	2.999	3.32	3.63
202	382.7	2.265	2.298	2.338	2.379	2.417	2.457	2.497	2.536	2.564	2.602	2.642	2.707	2.777	2.845	2.911	2.970	3.29	3.60
204	383.5	2.244	2.277	2.317	2.358	2.394	2.434	2.474	2.512	2.541	2.578	2.617	2.682	2.751	2.818	2.882	2.943	3.26	3.57
206	384.4	2.223	2.257	2.297	2.337	2.372	2.411	2.451	2.488	2.518	2.554	2.592	2.657	2.725	2.791	2.854	2.917	3.24	3.54
208	385.2	2.202	2.237	2.277	2.317	2.351	2.389	2.429	2.464	2.496	2.531	2.568	2.633	2.700	2.765	2.827	2.892	3.21	3.51
210	386.0	2.182	2.218	2.258	2.297	2.331	2.367	2.407	2.441	2.474	2.508	2.544	2.610	2.675	2.740	2.801	2.867	3.18	3.48
212	386.8	2.162	2.199	2.239	2.276	2.311	2.346	2.385	2.419	2.451	2.485	2.520	2.587	2.650	2.716	2.776	2.842	3.15	3.45
214	387.6	2.143	2.180	2.220	2.255	2.291	2.325	2.364	2.397	2.428	2.463	2.496	2.564	2.626	2.692	2.752	2.817	3.12	3.42
216	388.4	2.124	2.162	2.202	2.234	2.271	2.304	2.343	2.375	2.405	2.442	2.473	2.542	2.603	2.669	2.729	2.792	3.09	3.39
218	389.2	2.105	2.143	2.183	2.214	2.252	2.283	2.323	2.354	2.382	2.421	2.451	2.520	2.580	2.646	2.706	2.768	3.07	3.36
220	390.0	2.086	2.124	2.164	2.194	2.233	2.263	2.303	2.333	2.360	2.400	2.430	2.498	2.557	2.624	2.684	2.744	3.04	3.33
222	390.7	2.068	2.105	2.145	2.176	2.213	2.243	2.283	2.312	2.340	2.380	2.409	2.476	2.535	2.602	2.662	2.721	3.01	3.30
224	391.5	2.050	2.086	2.126	2.158	2.193	2.224	2.263	2.292	2.320	2.360	2.389	2.454	2.513	2.580	2.640	2.699	2.98	3.27
226	392.3	2.032	2.067	2.107	2.140	2.174	2.205	2.244	2.273	2.301	2.341	2.369	2.432	2.491	2.559	2.618	2.677	2.96	3.24
228	393.0	2.015	2.048	2.088	2.123	2.155	2.187	2.225	2.254	2.282	2.322	2.350	2.411	2.470	2.538	2.596	2.655	2.93	3.22
230	393.8	1.998	2.029	2.069	2.106	2.136	2.169	2.206	2.235	2.263	2.303	2.332	2.390	2.450	2.517	2.575	2.633	2.91	3.19
232	394.5	1.981	2.012	2.051	2.089	2.120	2.152	2.187	2.216	2.244	2.284	2.314	2.371	2.431	2.497	2.553	2.611	2.89	..
234	395.3	1.965	1.996	2.034	2.072	2.104	2.135	2.169	2.198	2.226	2.265	2.296	2.353	2.412	2.477	2.532	2.589	2.87	..
236	396.0	1.949	1.980	2.018	2.055	2.088	2.119	2.151	2.180	2.208	2.247	2.278	2.335	2.394	2.457	2.511	2.567	2.84	..
238	396.8	1.933	1.965	2.002	2.038	2.072	2.103	2.133	2.163	2.191	2.229	2.260	2.317	2.376	2.437	2.490	2.546	2.82	..
240	397.5	1.917	1.950	1.986	2.021	2.056	2.087	2.116	2.146	2.174	2.211	2.243	2.299	2.358	2.418	2.469	2.525	2.80	..
242	398.2	1.902	1.935	1.970	2.005	2.040	2.070	2.099	2.129	2.157	2.193	2.225	2.281	2.339	2.398	2.449	2.505	2.77	..
244	398.9	1.887	1.920	1.954	1.989	2.023	2.053	2.083	2.113	2.141	2.175	2.207	2.263	2.320	2.379	2.430	2.485	2.75	..
246	399.7	1.872	1.905	1.939	1.973	2.006	2.036	2.067	2.097	2.125	2.158	2.189	2.245	2.302	2.360	2.411	2.466	2.73	..
248	400.4	1.857	1.890	1.924	1.957	1.989	2.019	2.051	2.081	2.109	2.141	2.171	2.227	2.284	2.341	2.393	2.448	2.71	..
250	401.1	1.843	1.876	1.909	1.941	1.973	2.003	2.035	2.066	2.094	2.124	2.154	2.210	2.266	2.322	2.376	2.430	2.69	..
255	402.9	1.809	1.840	1.873	1.904	1.936	1.967	1.997	2.027	2.055	2.085	2.114	2.169	2.224	2.279	2.333	2.385	2.640	..
260	404.5	1.776	1.806	1.838	1.868	1.900	1.932	1.961	1.989	2.018	2.047	2.076	2.130	2.184	2.238	2.291	2.342	2.592	..
265	406.2	1.743	1.773	1.805	1.834	1.866	1.897	1.926	1.953	1.982	2.011	2.039	2.092	2.145	2.198	2.251	2.301	2.546	..
270	407.9	1.711	1.742	1.773	1.802	1.833	1.863	1.892	1.919	1.948	1.976	2.003	2.056	2.108	2.160	2.212	2.261	2.502	..
275	409.6	1.680	1.712	1.742	1.771	1.801	1.830	1.859	1.886	1.915	1.942	1.968	2.021	2.072	2.123	2.174	2.222	2.459	..
280	411.2	1.651	1.683	1.712	1.741	1.770	1.798	1.827	1.854	1.883	1.909	1.934	1.987	2.037	2.087	2.137	2.184	2.418	..
285	412.8	1.623	1.654	1.683	1.712	1.740	1.768	1.797	1.823	1.852	1.877	1.902	1.954	2.003	2.052	2.101	2.147	2.378	..
290	414.4	1.596	1.626	1.655	1.684	1.711	1.739	1.768	1.793	1.822	1.846	1.871	1.922	1.971	2.018	2.067	2.112	2.339	..
295	415.9	1.570	1.599	1.628	1.656	1.683	1.711	1.739	1.764	1.792	1.816	1.841	1.891	1.940	1.986	2.034	2.079	2.302	..
300	417.5	1.544	1.573	1.601	1.629	1.656	1.684	1.711	1.736	1.763	1.787	1.812	1.861	1.909	1.955	2.002	2.047	2.266	..

TABLE 1 SPECIFIC VOLUMES OF SATURATED AND SUPERHEATED STEAM, CU. FT. PER LB. (*Concluded*)

Pressure, lb. per sq. in. abs.	Saturation temperature, deg. fahr.	Superheat, deg. fahr. 0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	120°	140°	160°	180°	200°	300°	400°
305	419.0	1.519	1.548	1.575	1.603	1.630	1.658	1.684	1.709	1.735	1.759	1.794	1.832	1.879	1.925	1.971	2.016	2.231	..
310	420.5	1.495	1.523	1.550	1.578	1.604	1.632	1.658	1.683	1.708	1.732	1.756	1.804	1.850	1.896	1.941	1.985	2.197	..
315	422.0	1.472	1.499	1.526	1.554	1.579	1.607	1.632	1.657	1.682	1.705	1.729	1.777	1.822	1.867	1.912	1.955	2.164	..
320	423.4	1.449	1.476	1.503	1.531	1.555	1.583	1.607	1.632	1.657	1.679	1.703	1.750	1.795	1.839	1.883	1.926	2.132	..
325	424.9	1.427	1.454	1.481	1.508	1.532	1.560	1.583	1.608	1.632	1.654	1.678	1.724	1.769	1.812	1.855	1.898	2.101	..
330	426.3	1.406	1.432	1.459	1.486	1.510	1.537	1.560	1.584	1.608	1.630	1.654	1.699	1.743	1.786	1.828	1.871	2.071	..
335	427.7	1.385	1.411	1.438	1.464	1.488	1.515	1.537	1.561	1.584	1.606	1.630	1.675	1.718	1.761	1.802	1.844	2.042	..
340	429.1	1.365	1.391	1.417	1.443	1.467	1.493	1.515	1.539	1.561	1.583	1.607	1.651	1.694	1.736	1.777	1.818	2.013	..
345	430.5	1.345	1.371	1.397	1.423	1.447	1.472	1.493	1.517	1.539	1.561	1.584	1.628	1.670	1.712	1.752	1.793	1.985	..
350	431.9	1.326	1.352	1.378	1.403	1.427	1.452	1.472	1.496	1.518	1.539	1.562	1.606	1.647	1.688	1.728	1.769	1.958	..
355	433.2	1.308	1.333	1.359	1.383	1.407	1.432	1.451	1.475	1.497	1.518	1.540	1.584	1.625	1.665	1.705	1.745	1.932	..
360	434.6	1.291	1.315	1.340	1.364	1.388	1.413	1.431	1.455	1.477	1.497	1.519	1.563	1.603	1.643	1.682	1.722	1.906	..
365	435.9	1.273	1.297	1.322	1.346	1.370	1.394	1.412	1.435	1.457	1.477	1.499	1.542	1.582	1.621	1.660	1.699	1.881	..
370	437.2	1.256	1.280	1.304	1.328	1.352	1.376	1.394	1.416	1.438	1.458	1.480	1.522	1.561	1.600	1.639	1.677	1.857	..
375	438.5	1.239	1.263	1.287	1.311	1.334	1.357	1.376	1.398	1.419	1.439	1.461	1.503	1.541	1.580	1.618	1.656	1.833	..
380	439.8	1.223	1.247	1.270	1.294	1.317	1.339	1.358	1.380	1.401	1.421	1.443	1.484	1.522	1.560	1.598	1.635	1.810	..
385	441.0	1.207	1.231	1.254	1.277	1.300	1.322	1.341	1.363	1.383	1.403	1.425	1.466	1.503	1.541	1.578	1.615	1.788	..
390	442.3	1.192	1.216	1.238	1.261	1.284	1.306	1.325	1.346	1.366	1.386	1.408	1.448	1.485	1.522	1.559	1.595	1.766	..
395	443.5	1.177	1.201	1.223	1.246	1.268	1.290	1.309	1.330	1.350	1.369	1.391	1.431	1.467	1.504	1.541	1.576	1.745	..
400	444.8	1.162	1.186	1.208	1.231	1.253	1.275	1.294	1.314	1.334	1.353	1.374	1.414	1.450	1.487	1.523	1.558	1.725	..
410	447.2	1.134	1.157	1.179	1.202	1.223	1.245	1.264	1.283	1.303	1.322	1.342	1.382	1.417	1.453	1.488	1.522	1.685	..
420	449.6	1.107	1.130	1.151	1.174	1.194	1.216	1.235	1.254	1.273	1.293	1.311	1.351	1.385	1.420	1.455	1.488	1.647	..
430	451.9	1.081	1.104	1.124	1.147	1.167	1.188	1.207	1.226	1.244	1.264	1.282	1.321	1.354	1.389	1.423	1.455	1.611	..
440	454.2	1.056	1.079	1.099	1.121	1.141	1.161	1.181	1.199	1.217	1.237	1.254	1.292	1.325	1.359	1.392	1.423	1.576	..
450	456.5	1.033	1.055	1.075	1.096	1.116	1.136	1.156	1.173	1.191	1.211	1.227	1.264	1.297	1.330	1.362	1.392	1.543	..
460	458.7	1.010	1.032	1.052	1.072	1.082	1.111	1.132	1.148	1.166	1.186	1.201	1.237	1.270	1.302	1.333	1.362	1.511	..
470	460.9	0.988	1.010	1.030	1.049	1.069	1.087	1.108	1.124	1.142	1.162	1.176	1.211	1.244	1.275	1.306	1.334	1.480	..
480	463.1	0.967	0.989	1.008	1.027	1.047	1.064	1.085	1.101	1.119	1.138	1.152	1.186	1.219	1.249	1.278	1.307	1.450	..
490	465.2	0.947	0.968	0.987	1.005	1.025	1.042	1.063	1.079	1.096	1.115	1.129	1.163	1.195	1.224	1.252	1.281	1.421	..
500	467.2	0.928	0.948	0.967	0.985	1.004	1.021	1.042	1.057	1.074	1.093	1.107	1.141	1.172	1.200	1.228	1.256	1.394	..
510	469.3	0.910	0.929	0.948	0.966	0.984	1.001	1.022	1.036	1.053	1.072	1.086	1.119	1.150	1.177	1.205	1.232	1.368	..
520	471.3	0.892	0.911	0.930	0.948	0.965	0.982	1.002	1.016	1.033	1.052	1.066	1.098	1.128	1.155	1.182	1.209	1.343	..
530	473.3	0.875	0.894	0.912	0.930	0.947	0.963	0.983	0.997	1.014	1.032	1.046	1.078	1.107	1.134	1.160	1.187	1.319	..
540	475.3	0.858	0.877	0.895	0.913	0.929	0.945	0.965	0.979	0.996	1.013	1.027	1.058	1.087	1.114	1.139	1.166	1.295	..
550	477.2	0.842	0.861	0.874	0.896	0.912	0.928	0.947	0.962	0.978	0.995	1.009	1.039	1.068	1.094	1.119	1.146	1.272	..
560	479.1	0.827	0.845	0.863	0.880	0.896	0.912	0.930	0.945	0.961	0.977	0.992	1.021	1.049	1.075	1.100	1.126	1.250	..
570	481.0	0.812	0.830	0.848	0.865	0.880	0.896	0.913	0.929	0.944	0.960	0.975	1.003	1.031	1.057	1.082	1.107	1.229	..
580	482.8	0.797	0.815	0.833	0.850	0.865	0.881	0.897	0.913	0.928	0.944	0.959	0.986	1.014	1.039	1.064	1.089	1.209	..
590	484.7	0.783	0.801	0.818	0.836	0.850	0.866	0.882	0.898	0.913	0.928	0.943	0.970	0.997	1.022	1.047	1.072	1.190	..
600	486.5	0.769	0.787	0.804	0.822	0.836	0.851	0.867	0.883	0.898	0.913	0.927	0.954	0.981	1.006	1.030	1.055	1.171	..
610	488.3	0.756	0.773	0.790	0.808	0.822	0.837	0.852	0.869	0.884	0.898	0.912	0.939	0.965	0.990	1.014	1.039	1.153	..
620	490.1	0.743	0.759	0.776	0.795	0.809	0.823	0.838	0.855	0.870	0.884	0.897	0.924	0.950	0.975	0.999	1.023	1.135	..
630	491.8	0.731	0.746	0.763	0.782	0.796	0.810	0.825	0.842	0.856	0.870	0.883	0.910	0.935	0.960	0.984	1.008	1.118	..
640	493.5	0.719	0.734	0.751	0.769	0.784	0.798	0.812	0.829	0.842	0.856	0.870	0.896	0.921	0.945	0.969	0.993	1.102	..
650	495.2	0.707	0.723	0.739	0.757	0.772	0.786	0.800	0.816	0.829	0.843	0.857	0.882	0.907	0.931	0.955	0.978	1.086	..
660	496.9	0.696	0.712	0.727	0.745	0.760	0.774	0.788	0.804	0.816	0.830	0.844	0.869	0.893	0.917	0.941	0.964	1.071	..
670	498.6	0.685	0.701	0.716	0.733	0.748	0.763	0.776	0.792	0.804	0.818	0.831	0.856	0.880	0.904	0.928	0.950	1.056	..
680	500.2	0.675	0.691	0.705	0.722	0.737	0.752	0.765	0.780	0.792	0.806	0.818	0.843	0.867	0.891	0.915	0.937	1.041	..
690	501.8	0.665	0.681	0.695	0.711	0.726	0.741	0.754	0.769	0.781	0.794	0.806	0.831	0.855	0.878	0.902	0.924	1.027	..
700	503.4	0.655	0.671	0.685	0.700	0.716	0.730	0.743	0.758	0.770	0.783	0.794	0.819	0.843	0.866	0.890	0.911	1.013	..
710	505.0	0.645	0.661	0.675	0.689	0.706	0.719	0.732	0.747	0.759	0.772	0.783	0.807	0.831	0.854	0.878	0.898	1.000	..
720	506.6	0.636	0.651	0.665	0.679	0.696	0.708	0.722	0.736	0.748	0.761	0.772	0.796	0.819	0.842	0.866	0.886	0.987	..
730	508.1	0.627	0.642	0.656	0.669	0.686	0.698	0.712	0.726	0.738	0.751	0.761	0.785	0.808	0.831	0.855	0.874	0.974	..
740	509.6	0.618	0.633	0.647	0.660	0.676	0.689	0.703	0.716	0.728	0.741	0.751	0.775	0.797	0.820	0.844	0.863	0.962	..
750	511.1	0.609	0.624	0.638	0.651	0.667	0.680	0.694	0.706	0.718	0.731	0.741	0.765	0.787	0.809	0.833	0.852	0.950	..
775	514.9	0.588	0.603	0.617	0.629	0.644	0.657	0.671	0.682	0.694	0.707	0.716	0.741	0.761	0.783	0.807	0.825	0.922	..
800	518.5	0.568	0.582	0.596	0.609	0.623	0.636	0.650	0.660	0.672	0.685	0.694	0.718	0.738	0.759	0.783	0.800	0.896	..
825	522.0	0.549	0.562	0.576	0.590	0.603	0.616	0.630	0.639	0.652	0.664	0.673	0.696	0.716	0.736	0.760	0.776	...	..
850	525.5	0.532	0.544	0.558	0.571	0.584	0.597	0.610	0.620	0.632	0.644	0.653	0.676	0.695	0.715	0.738	0.754	...	..
875	528.9	0.516	0.527	0.541	0.553	0.566	0.579	0.591	0.602	0.613	0.625	0.634	0.657	0.675	0.695	0.717	0.733	...	..
900	532.3	0.500	0.511	0.525	0.537	0.550	0.562	0.574	0.584	0.596	0.607	0.617	0.638	0.657	0.676	0.697	0.713	...	..
925	535.6	0.485	0.496	0.510	0.522	0.535	0.546	0.558	0.567	0.580	0.590	0.601	0.620	0.640	0.658	0.678	0.694	...	..
950	538.8	0.471	0.482	0.496	0.507	0.520	0.531	0.542	0.552	0.564	0.574	0.585	0.604	0.623	0.641	0.660	0.676	...	..
975	541.9	0.457	0.469	0.482	0.493	0.506	0.517	0.527	0.537	0.549	0.559	0.570	0.589	0.607	0.625	0.643	0.659	...	..
1000	544.9	0.444	0.456	0.469	0.480	0.493	0.503	0.514	0.523	0.535	0.545	0.556	0.574	0.592	0.610	0.627	0.643	...	..
1025	547.9	0.432	0.444	0.457	0.468	0.480	0.490	0.501	0.510	0.522	0.532	0.542	0.560	0.578	0.596	0.612	0.628	...	..
1050	550.8	0.421	0.433	0.445	0.456	0.468	0.478	0.489	0.497	0.509	0.519	0.529	0.547	0.564	0.582	0.598	0.614	...	..
1075	553.7	0.410	0.422	0.434	0.445	0.456	0.466	0.477	0.485	0.497	0.507	0.516	0.534	0.551	0.569	0.585	0.600	...	..
1100	556.6	0.400	0.412	0.423	0.434	0.445	0.455	0.466	0.474	0.485	0.495	0.504	0.522	0.539	0.556	0.572	0.588	...	..
1125	559.4	0.390	0.402	0.413	0.423	0.434	0.444	0.455	0.463	0.474	0.484	0.492	0.510	0.527	0.544	0.560	0.576	...	..
1150	562.2	0.380	0.392	0.403	0.413	0.424	0.434	0.444	0.453	0.463	0.473	0.481	0.499	0.516	0.532	0.548	0.564	...	..
1175	565.0	0.370	0.382	0.393	0.403	0.414	0.424	0.433	0.443	0.452	0.462	0.470	0.488	0.505	0.521	0.537	0.552	...	..
1200	567.7	0.361	0.373	0.384	0.393	0.404	0.414	0.423	0.433	0.442	0.452	0.460	0.478	0.494	0.510	0.526	0.541	...	..

This expression, which can be derived from the first and second laws of thermodynamics, was reasonably satisfactory, though since its use probably involved cumulative errors a check at saturation was highly desirable.

Such a check was afforded by the Clapeyron relationship. The Goodenough total heats of the liquid with the new saturation total heats were used to find the latent heat of vaporization which, inserted in the Clapeyron equation, gave a set of saturation specific volumes which agreed well with those obtained from Equation [5] up to about 500 lb. per sq. in., but differed by about 0.8 per cent at 750 lb. per sq. in. The saturation specific volumes finally accepted differed from those obtained from the Clapeyron relationship by a maximum of 0.36 per cent, and lay between them and the values obtained from Equation [5]. The specific volumes previously calculated from $\left(\frac{\partial\phi}{\partial p}\right)_T$ were altered slightly at the lower superheats to agree with the saturation values. The final specific-volume data are given in Table 1.

Extrapolation to 1200 Lb. per Sq. In. Absolute

Fig. 9 shows a high-pressure extrapolation of the 750-lb. per sq. in. Mollier diagram. This extrapolation was made graphically on a chart of differences between the new data and the Goodenough formulas which involved only small quantities. The extrapolation itself should be quite good above 650 deg. fahr. and along the saturation line. The intermediate region was more difficult to extrapolate, and consequently that part of the chart is the least reliable. Fortunately, from the turbine designer's point of view, that part is also the least important.

Comparisons with Other Steam Tables

Tables 2 and 3 consist of comparisons of specific volumes and available energies obtained from various published steam tables with those from the new data. Figs. 5, 6, and 7 show the differences between the new data and the Goodenough formulations. The magnitude of the total-heat differences at low superheat is accounted for by the fact that specific heats from the new data rise rapidly near saturation as do the Knoblauch determinations, while the Goodenough formulation was based on a much flatter curve. However, since there are corresponding differences between the entropy values, the available energies obtained from these two steam tables are in close agreement.

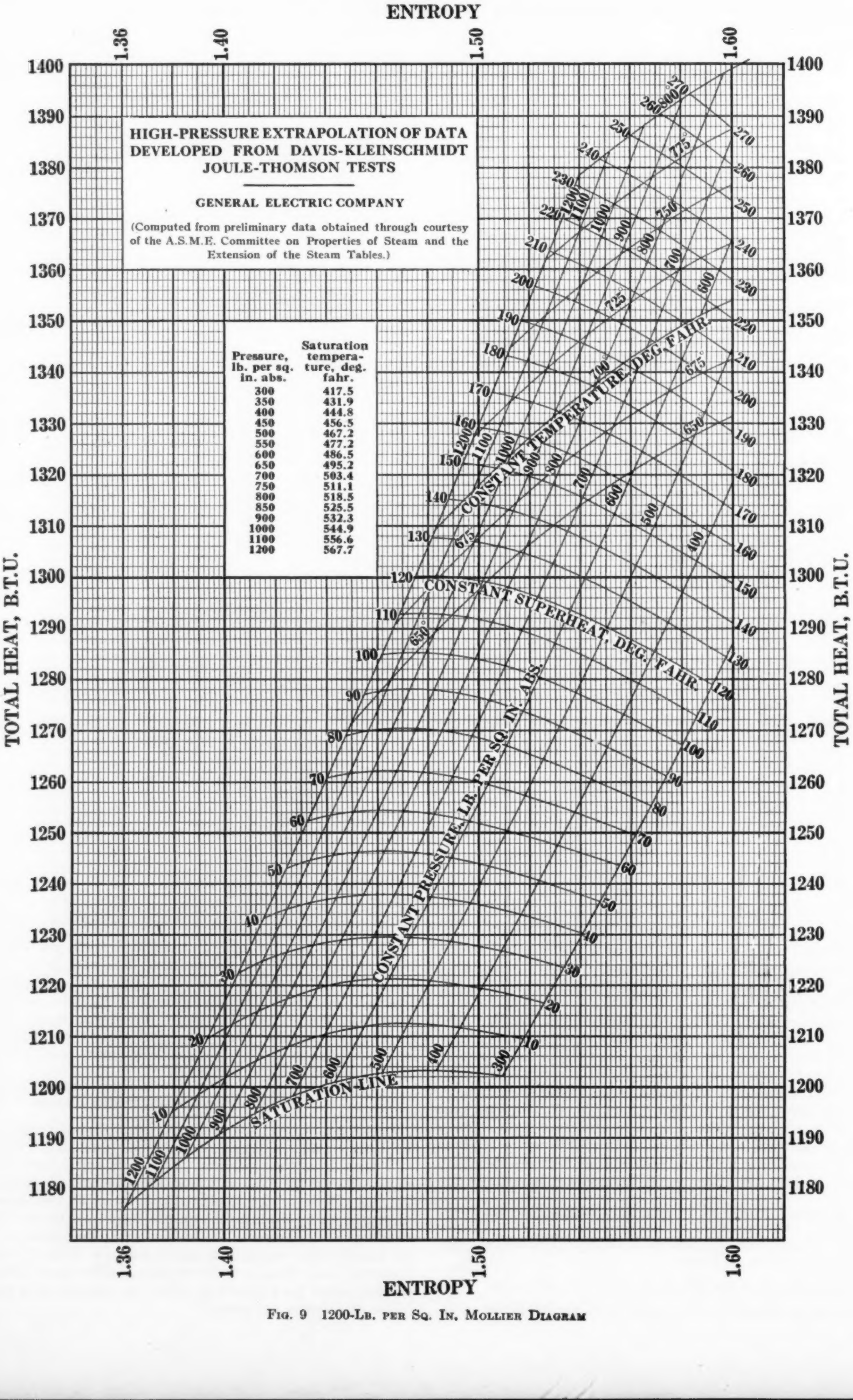


Fig. 9 1200-Lb. per Sq. In. Mollier Diagram

TABLE 2 COMPARISON OF STEAM TABLES AT HIGH PRESSURES

	Marks and Davis	Stodola	Callendar	Knoblauch	Goodenough	New Chart
Upper limit of table (lb. per sq. in.)	600	1422	2000	850	800	1200
Means of extrapolation	graphic	.....	.....	graphic	formula	.....
1000 LB. PER SQ. IN. ABS., 750 DEG. FAHR.:						
Specific volume (cu. ft. per lb.)	.....	0.654	0.677	0.625	0.659	0.648
Adiabatic heat drop to 200 lb. per sq. in. abs. (B.t.u. per lb.)	163.8	163.8	166.6	164.7	162.8	162.9
500 LB. PER SQ. IN. ABS., 725 DEG. FAHR.:						
Specific volume (cu. ft. per lb.)	1.402	1.346	1.362	1.318	1.356	1.340
Adiabatic heat drop to 150 lb. per sq. in. abs. (B.t.u. per lb.)	126.4	131.7	132.1	130.5	131.8	131.1

SUMMARY

The new steam chart and tables are based on the Harvard throttling experiments which reach pressures as high as 565 lb. per sq. in. absolute and temperatures in the neighborhood of 660 deg. fahr. The data for temperatures below 320 deg. fahr.—temperatures not covered by the new Joule-Thomson experiments—are obtained from the Marks and Davis steam tables.

The development of the Harvard data involved the use of the only other extensive series of experiments that have been made on superheated steam above 200 lb. per sq. in., namely, the Knoblauch specific-heat determinations. These data extended to about 420 lb. per sq. in. The c_{p_0} values plotted on Fig. 4 are evidence that the two sets of data are mutually consistent.

TABLE 3 AVAILABLE ENERGY TO 1½ IN. MERCURY ABSOLUTE (B.T.U. PER LB.)

Initial Conditions: Pressure, lb. per sq. in. abs.	Quality	Callendar	Goodenough	New Chart
1000	Dry	449.2	427.8	426.4
1000	200 deg. superheat	516.7	507.4	509.0
750	Dry	433.2	417.8	418
750	150 deg. superheat	480.1	471.7	474
750	235 deg. superheat	506.7	510.0	501.7
500	Dry	409.0	401.8	400.9
500	150 deg. superheat	451.4	448.0	447.8
500	280 deg. superheat	489.0	486.45	486.2
250	Dry	366.3	362.8	362.5
250	150 deg. superheat	402.0	399.8	399.7
250	345 deg. superheat	453.4	452.25	451.0

It is not to be supposed that the new chart and tables are presented as the final word on the properties of steam in the region they cover. The rapid increase in the pressures used in steam-turbine practice made evident the urgent need for more reliable data on steam and prompted this development of the Harvard data. Further information yielded by the A.S.M.E. Steam Research Program will be eagerly awaited. In the meantime these new charts and tables will be of service as a development of the most extensive and dependable empirical data that have yet been published on steam at high pressures.

Progress in Steam Research

THE fourth annual session on Progress in Steam Table Research was held on Wednesday afternoon, December 2, during the 1925 Annual Meeting of the A.S.M.E. Dr. A. M. Greene, Jr., of the Executive Committee, Steam Table Fund, presided.

George A. Orrok, Chairman of the Executive Committee, Steam Table Fund, reported on the financial status of the research and acknowledged the indebtedness of the Fund to the General Electric Company for the work that corporation had contributed in computing the tables and Mollier diagrams forming a part of Mr. Keenan's paper and included elsewhere in this issue of MECHANICAL ENGINEERING.

N. S. Osborne and H. F. Stimson, of the United States Bureau of Standards, reported that the construction of the entire apparatus for measuring the heat content of water and steam was practically completed and the stage of assembling under way.

L. B. Smith, of the Massachusetts Institute of Technology, reported the completion of measurements of the vapor pressures and specific volumes of water over the temperature range 392–680 deg. fahr. (200–360 deg. cent.), reviewed the field under investigation, and described the experimental method employed.

R. V. Kleinschmidt, of Harvard University, presented the final report of the experimental work at that institution on the Joule-Thomson effect, and discussed a number of points that had been raised during the course of the work.

F. G. Keyes, of the Massachusetts Institute of Technology, dealt with means of making pressure and temperature measurements in connection with the steam research work being carried on at the Institute.

J. H. Keenan, of the General Electric Company, Schenectady, N. Y., presented a report embodying a table of the specific volumes of saturated and superheated steam for pressures up to 1200 lb. per sq. in. abs. and the corresponding saturation temperature of 567.7 deg. fahr., and 750- and 1200-lb. Mollier diagrams, based on the Joule-Thomson experiments of Messrs. Davis and Kleinschmidt at Harvard University.

Harvey N. Davis, of Harvard University spoke of the work ahead in correlating the various sets of data that had been obtained in the course of the research, in order to prepare the final desideratum—the steam tables.

R. C. H. Heck, of Rutgers College, compared the new information provided by the research with formulas which he had proposed in 1920 but had not hitherto computed.

The various reports presented are supplementary to those published in MECHANICAL ENGINEERING for February, 1924 (p. 81), and February, 1925 (p. 103), and their texts immediately follow.

Report of the Executive Committee of the Steam Table Fund

GEORGE A. ORROK, Chairman of the Executive Committee of the Steam Table Fund, reported as follows:

At the meeting of the Steam Table Fund in December, 1924, it was reported that the total subscriptions to the Fund had amounted to $30,075, and that this money had been expended and about $4000 more would be required to cover the work done at Harvard University and Massachusetts Institute of Technology up to that time. During the subsequent six months, although effort was put forth, only $1350 additional in subscriptions was secured.

Because the Fund was responsible to Harvard University and Massachusetts Institute of Technology for payment of their bills covering work performed, as well as for the salaries of the men engaged on the work of the Steam Table at the Bureau of Standards, it was decided by your Executive Committee, in June, 1925, to take advantage of an offer from the Council of the A.S.M.E. of a loan of $8000 until relief was available in the form of additional subscriptions.

At this juncture it was estimated that the work could be completed in two years, at a cost of approximately $30,000 additional to the amount already subscribed, which would be well within the original estimate of $105,000; and a meeting was held between the Executive Committee of the Steam Table Fund and three of the largest and most interested manufacturers (General Electric Company, Babcock & Wilcox Company, and the Superheater Company) at which the manufacturers agreed to raise $15,000 more provided the utilities would subscribe a like amount. There has since been a hearty response on the part of the utilities, and the Fund has received from them $12,500, with more in prospect, and the manufacturers stand ready to duplicate the utilities' subscription when they are called upon. The Fund has therefore been enabled to repay to the A.S.M.E. the $8000 which it borrowed.

To summarize:

The actual receipts to date amount to......	$45,375.00
The actual disbursements amount to.......	42,153.03
Leaving a balance on hand as of December 1, 1925, of...........................	$ 3,221.97

In addition to the above, the Bureau of Standards had disbursed from its own funds up to May 15, 1925, $20,460 on the work of the Steam Table.

The Steam Table Fund is indebted to the General Electric Company for the computation of the new steam table and Mollier charts for saturated and superheated steam, developed from the Davis-Kleinschmidt Joule-Thomson tests at Harvard. This entailed an immense amount of work, which the General Electric Company have generously contributed to the research.

The work at Harvard is practically completed and final payments have been made. The work at the Massachusetts Institute of Technology you will hear reported on by Professor Keyes, and Mr. Osborne will report on the work done by the Bureau of Standards in the past year.

We have had another suggestion regarding the supersaturation problem, and negotiations are under way which may result in entertaining a proposal for the settlement of this problem.

Report on Progress in Steam Research at the Bureau of Standards

BY N. S. OSBORNE[1] AND H. F. STIMSON,[2] WASHINGTON, D. C.

A YEAR ago we reported that the construction of the central unit of the apparatus for measuring the heat content of water and steam was nearly completed, and that the accessories would be the next to build. This task has progressed steadily and we can now report that the construction of the entire apparatus is practically complete and that the stage of assembling is under way.

It is impossible to anticipate far in advance all the details of design, construction, and test which must be observed and studied in order to insure reliability of the results. This project to observe calorimetrically a group of processes which exhibit the thermodynamic behavior of water or steam along the saturation limit up to 1250 lb. per sq. in. as an accurate basis for steam-table formulation is being undertaken for the first time.

If there were available at the outset sufficient data on the chemical, mechanical, electrical, and thermal properties of materials, and if it were possible to find these properties suitably combined, it would be an easy matter to draw up the complete design in advance; but when so many uncertainties are encountered the work must be proved out step by step as the design and construction proceed. It is necessary to have close coöperation between the shop and the laboratory, and the progress of this work is due largely to our fortunate choice of instrument makers.

The main features of the design have remained as originally projected, and the progress of the past year has consisted in the successive completion of various details. It may be of interest to mention several of these features and describe them in part.

The temperature-measuring unit includes an extension of the envelope or shell surrounding the central calorimeter shell. This extension is a heavy-walled copper block with circular steps inside like an amphitheater. These steps afford space for attaching the reference junctions of thermoelements, the working junctions of which are applied either to the calorimeter shell, the envelope, or the connecting tubes. Resistance thermometers enter receptacles on the outside of the block and measure its temperature as a reference indication, and the well-conducting copper mass forms a thermal union between the thermometers and the thermoelements.

The thermoelements are of chromel and copel wire with gold leads, and mica is used for insulation. The junctions are connected thermally to the metal body, but insulated electrically so that several of the elements may be joined in series for indicating the temperature of the calorimeter relative to the block. Temperature changes in the calorimeter and contents are thus referred to the resistance thermometer and so measured. These thermoelements also indicate the relative temperature of calorimeter and envelope for control and measurement of thermal leakage. The gold leads extend from the reference chamber out through the vacuum connection to the seal at room temperature. There are 28 such leads assembled in a single bundle with mica insulation. The heat conducted away by these leads is prevented from affecting the indications of the thermocouples by interposing thermal "tie downs" where they will be effective. The importance of this feature may be appreciated by noting that two extra "tie downs" reduce the error in temperature indication which otherwise might be nearly a degree to one ten-thousandth of a degree, a negligible amount.

The top of the enveloping vacuum chamber is sealed by a flexible metal diaphragm to accommodate the differential expansion between the suspended calorimeter system and the vessel which surrounds it.

The temperature-control bath is primarily for the purpose of protecting the heat-measuring unit from indiscriminate loss or gain of heat so that all the heat which the water absorbs in a certain change of state may be measured and accounted for. The temperature of the envelope must be closely controlled not only when making constant-temperature experiments, but also in experiments where the calorimeter is heated from one temperature to another. For this reason the volume of the control liquid has been kept small so that it may be made to respond quickly to a change, and the form of the circulation has been so determined as to utilize efficiently the heat-exchanging power of the stream. A very small centrifugal pump is ample to circulate the liquid rapidly. The electric heating and automatic control of this bath are matters of familiar laboratory technique. The oil for this bath has been selected for its stability at the service temperatures combined with a suitably low viscosity. The oil is protected from exposure to air where hot, thus lessening the deterioration by oxidation and the danger of flashing. The overflow and feed reservoirs will keep the vessel full, compensating for the thermal expansion of about 40 per cent in the 540-deg. range.

Valves for controlling the flow in the connecting lines of the water system were mentioned a year ago as constituting a special problem in refined construction. This problem has been satisfactorily solved, and the sixteen valves required have been made according to the four different special designs developed. These valves are all of the diaphragm type. The development of a reliable diaphragm to seal between the movable stem and the valve body has avoided the use of a stuffing box, which is particularly objectionable at high temperatures. The material of the four valves which operate at high temperature is noble metal wherever the steam comes in contact. In the valves which are in the outside connections and do not get above the boiling point of water, tin has been permitted as being immune to attack by water.

The first valve which the vapor encounters after leaving the calorimeter is a throttle to reduce the pressure to less than one atmosphere on its way to the condensing receiver. Throttling takes place in this valve across the flat annular passage between the flat seat and the flat stem end. The stem is moved by a threaded nut rotated by worm gear, thus giving delicate control of the resistance to flow.

From the throttle valve the vapor goes to the distributing line, which branches to three shut-off valves. These valves are intended to be either wide open or tight shut, and throttling is avoided. To close one of these valves a flat stem end of soft silver is pressed against a hard silver-palladium seat and is lifted free to open the valve. The mechanism to effect this operation is positive, quick-acting, and adjustable, and avoids damage to the seat by too tight closing. The vapor lines up to these shut-off valves are silver-palladium for strength, but from here out to the reservoirs silver tubing is used. The shut-off valves for the reservoirs are similar in design but of larger size, to accommodate a suitable rate of flow of the vapor after its pressure is still further reduced by passing it through an orifice.

The stuffing box for the calorimeter-pump drive shaft is a nice piece of the instrument maker's workmanship. The part of the shaft which passes through this box is of stellite. Aside from the tin in the receiver valves, this metal and the packing itself are the only base materials in contact with the water under observation. The stuffing box is kept cool by a water jacket at the top. The body of the box is of monel metal, the water passages being silver-lined. The packing is in two parts with an intermediate space for detecting, measuring, or compensating leakage of water from the calorimeter system. When the calorimeter is operating at 575 deg. fahr. the thrust of about 7 lb. exerted on the shaft 0.12 in. diameter is taken on a $^1/_8$-in. ball bearing. This shaft runs at

[1] Physicist, U. S. Bureau of Standards.
[2] U. S. Bureau of Standards.

about 900 r.p.m. Connection with the pump wheel is made through a thin tubular section about $6^1/_2$ in. long. Below, the shaft is connected with the driving motor and a tachometer. The design and construction of a liquid tachometer for indicating the pump speed was a trifling detail, because it involved nothing novel either in principle, in working conditions, or in materials.

The provision for making pressure measurements has required some special construction in addition to the piston gages on which the pressures are to be observed. In order to transmit the working pressure within the calorimeter out through the temperature gradient of 540 deg. fahr. to the gage without incurring uncertainty of the amount, purity, and energy of the water in the calorimeter system, a cell or capsule has been designed in which a flexible thin metal diaphragm is interposed in the connection. The small resistive force of this diaphragm can be observed and accounted for in the pressure measurements.

The throttling device for measurements on superheated vapor which existed on paper a year ago has been completed and tested with air. This is another example of extremely fine metal work. An 80-pitch thread is cut on the inside of the silver-palladium tube which leads the vapor out. A silver-gold plug is threaded to fit this tube which is about $^1/_8$ in. in diameter. The plug is about $^1/_2$ in. long. In the measurements on saturated liquid and vapor this throttle is not used and may be either removed entirely or placed below the inlet. When the throttle is in operation the vapor passes through the channel between the threaded tube and plug. The nicety of fit of these threads determines one element of the resistance to vapor flow, which is fixed for any one plug in the making. The length of the screw thread through which the flow passes is the other factor, and this furnishes the feature of adjustability which is essential to this method of measuring the heat content of superheated steam. By varying the position of the plug in the tube different degrees of throttling may be obtained.

Means of access to the interior of the calorimeter have been provided so that the position of the plug may be adjusted by a special tool. The throttle has been designed to permit any degree of throttling from 1250 lb. per sq. in. down to atmospheric pressure for a vapor flow of from 1 g. per min. to 10 g. per min. The coiled tube through which the vapor passes to reheat it after the throttling, has been made as long as could be conveniently stowed in the available space. The proportioning of this tube was limited by the space, by the cooling effect of pressure drop in the tube itself, and by the reheating effect by the condensing vapor on the outside. About six feet of tube were used. In the worst case, which is at low pressure, the throttled vapor should be brought to within 0.01 deg. of the initial saturation temperature. Thermocouples will be placed on the outflow tube to obtain the temperature of the vapor.

A supporting structure has been erected which will accommodate the calorimeter and the accessories, which are most conveniently located near it.

The general principles of the method and many of the features of the proposed equipment have been described previously and need no elaboration at this time. It may be recalled that the basic idea is to account accurately for the energy exchanged by the water in a few characteristic processes and thus determine its thermal behavior. The elusiveness of heat energy presents the main difficulty to be combated by the refinements employed in the calorimetric apparatus.

It is very evident that even though the method itself may be a model of simplicity, the apparatus is far from simple. In preparing for such a comprehensive series of physical measurements different courses are open to the experimenter. He may in the hope of rapid progress avoid complicated and refined construction which is laborious, expensive, and slow to prepare, trusting to experimental skill and copious observations to overcome the handicaps of imperfect equipment.

On the contrary, the difficulties of manipulation and the sources of error inherent in the nature of the measurements may be recognized at the outset and dealt with in detail in preparing plans for the equipment. Refinements may be developed to simplify the manipulation and the experimental processes to avoid anomalous discrepancies and systematic errors in the measurements.

In the present instance this course has been chosen not only because it favors reliability of the steam data sought, but because it seems quickest in the end.

Report on Progress in Steam Research at the Massachusetts Institute of Technology

By L. B. Smith,[3] Cambridge, Mass.

Since Dr. Keyes reported a year ago, the vapor pressures of water have been measured from 200 deg. cent. to 360 deg. cent., or from 392 deg. fahr. to 680 deg. fahr. Measurements of the specific volumes of liquid water over the same temperature range have also been completed.

Before discussing the experimental results I should like to review very briefly the field which we have undertaken to investigate and the experimental method employed.

Let us consider a diagram in which we plot pressure against

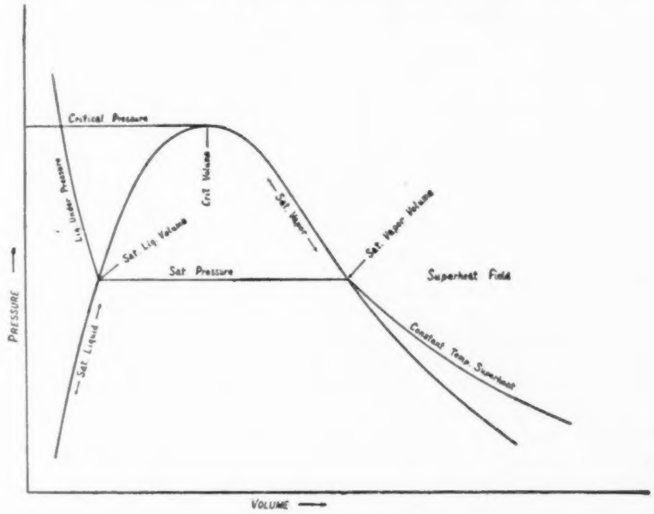


Fig. 1 Vapor Diagram

volume. The area below and bounded by the curve represents equilibrium between liquid and vapor. That portion to the left of the curve represents the conditions where the liquid can alone exist, while to the right and above the curve vapor can alone exist. This latter portion of the diagram is known as the superheated region.

The line drawn in Fig. 1 represents an isothermal or constant-temperature line, and indicates what will happen if we gradually compress a portion of the superheated vapor at constant temperature.

At the Massachusetts Institute of Technology we have undertaken to determine the *P*, *T*, *V* relations in the superheat, the liquid and vapor saturation volumes and pressures, and the specific volumes of the compressed liquid. The portion so far actually investigated is represented by the crosses on the isothermal.

Fig. 2 is a diagrammatic representation of the apparatus employed. *A* is the bomb containing the pure water under investigation. It is connected through the capillary tube *E* with the tube *B* containing liquid water and confined by mercury, represented by the block portion. The pressure is transmitted by the mercury to the gage *G*. At *C* is a piston whose displacement can be measured on the scale *D*. By displacing the piston *C* we are able to vary the amount of water in the bomb *A*. It is necessary to know the temperature of the water in the capillary where it emerges from the high temperature bath which is effected by surrounding the capillary with a water cooler.

Fig. 3 is a diagram of the actual apparatus. The high-temperature bath is shown at the right, together with the bomb, stirrer, heaters, thermal regulator, and resistance thermometer. *D* is the tube containing water and mercury. The riser *C* serves to make connection with the absolute-pressure gage *A*. The lower part of *C*, up to an insulated contact, is filled with mercury. Above

[3] Research Assistant, Research Laboratory of Physical Chemistry, Massachusetts Institute of Technology.

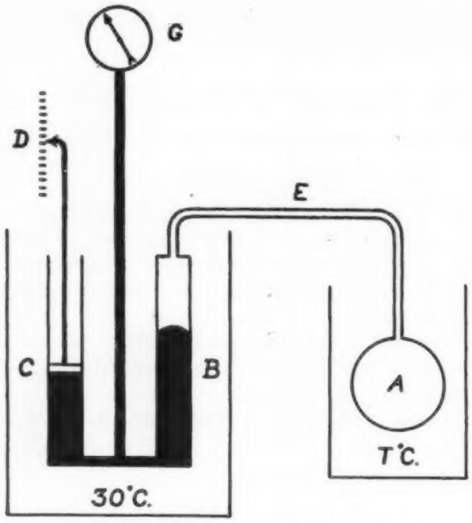


FIG. 2 DIAGRAMMATIC REPRESENTATION OF APPARATUS

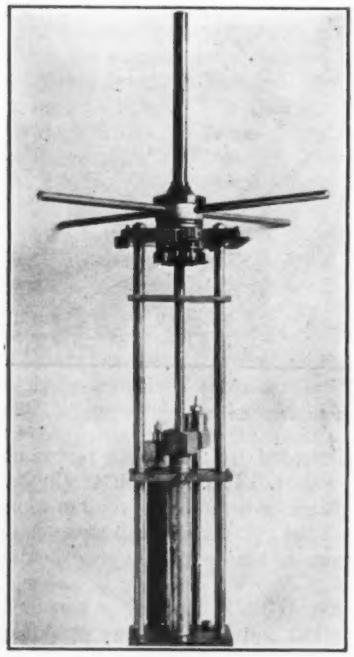


FIG. 5 VOLUME-MEASURING DEVICE

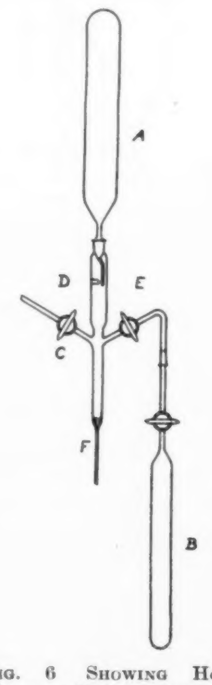


FIG. 6 SHOWING HOW WATER IS TRANSFERRED INTO THE BOMB OF THE APPARATUS

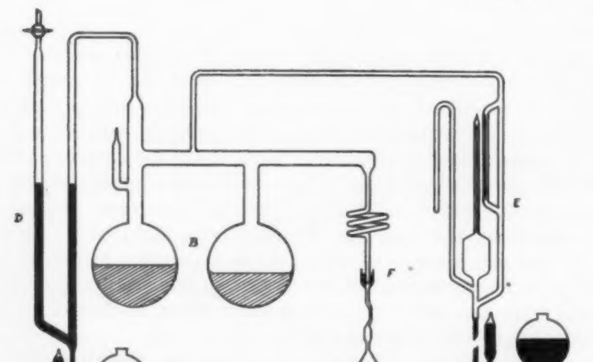


FIG. 7 DIAGRAMMATIC REPRESENTATION OF THE WATER-DISTILLING APPARATUS

the mercury, oil transmits the pressure. Electrical contact between the mercury surface and the insulated needle makes it possible to detect pressure equilibrium and also to maintain the mercury-oil surface at a fixed point. E is the volume-measuring piston.

Fig. 4 is a photograph of the partially assembled apparatus, showing the floating-piston pressure gage, the high-temperature bath, the nickel bomb, and some of the auxiliary electrical apparatus.

Fig. 5 shows the volume-measuring piston in some detail. The piston is forced into the displacement cylinder by rotating the

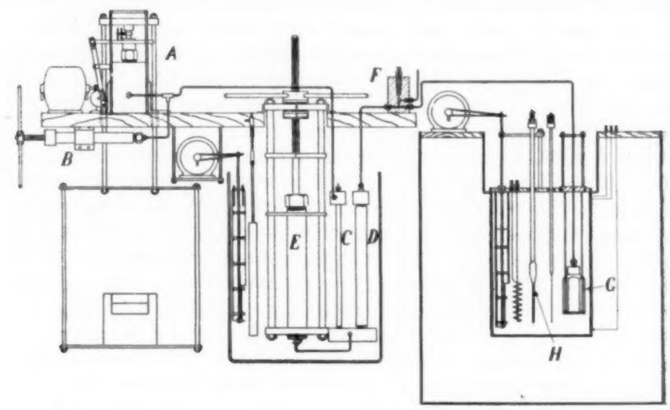


FIG. 3 DIAGRAM SHOWING DISPOSITION OF APPARATUS

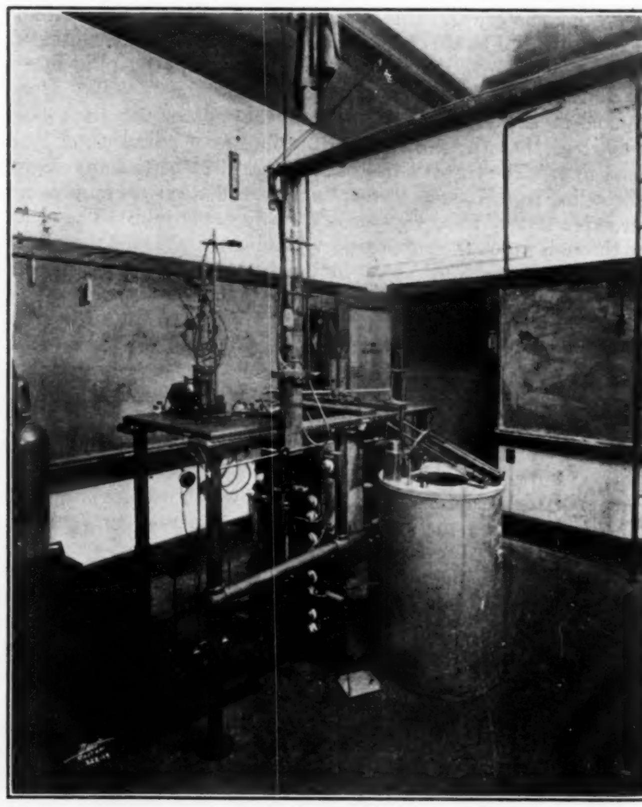


FIG. 4 VOLUME-DISPLACEMENT APPARATUS SET IN POSITION AND THE BATH IN WHICH IT IS IMMERSED

large nut at the top. The nut is provided with roller thrust bearings and has a revolution counter and a divided edge. One-thousandth of a turn, corresponding to about 0.00002 cu. in., may be readily estimated. To the right and rear of the compressor cylinder may be seen the contact riser, and to the left the tube containing mercury and water.

Water was purified and freed from air and other gases by vacuum distillation in the apparatus shown in Fig. 6. The tube A was finally filled and sealed off from the purification apparatus and its weight recorded.

Fig. 7 shows how the water was then transferred to the bomb. The tube A containing the water was joined by a ground-glass seal to the glass connector D. The nickel capillary F leads to the bomb through a monel-metal stop cock. The vessel B and the connector D were evacuated through the cock C and the monel stop cock was opened to the previously evacuated bomb. Cocks C and E were then closed and the tube A was rotated in the ground joint so as to break off the glass tip against the projection shown at D. This permitted the water to flow into the bomb. The monel

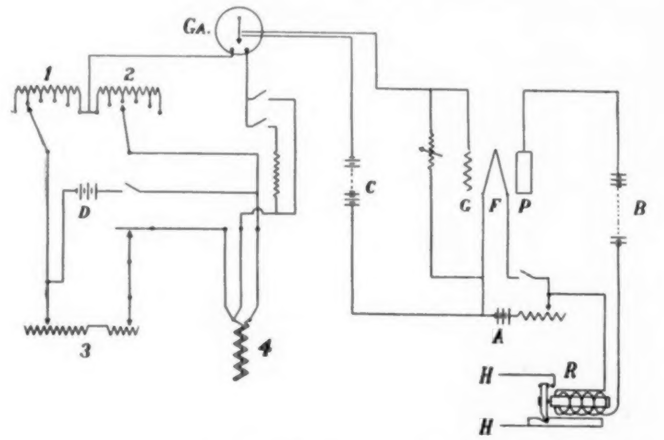


FIG. 8 DETAILS OF CIRCUIT OF DEVICE FOR AUTOMATICALLY MAINTAINING A DEFINITE TEMPERATURE IN THE BATH

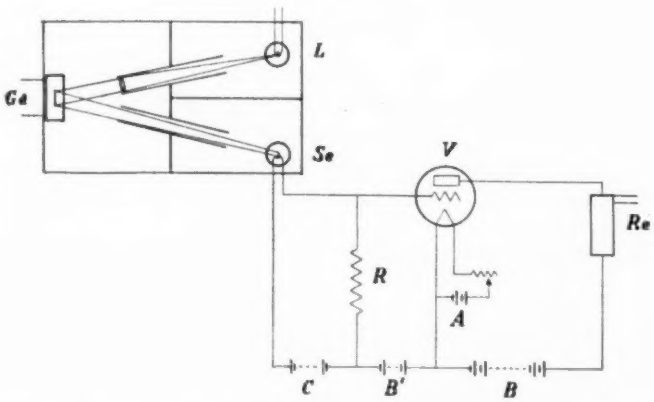


FIG. 9 DEVICE OF FIG. 8 WITH MIRROR INSTRUMENT REPLACING NEEDLE GALVANOMETER

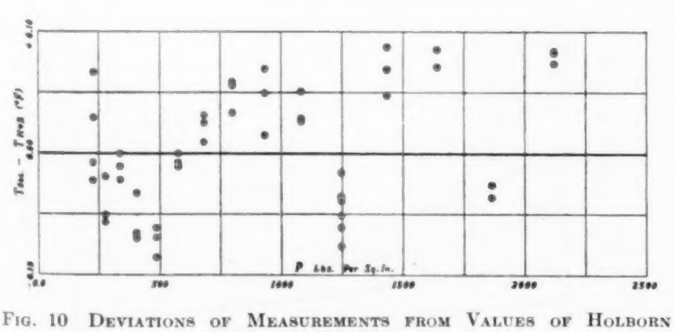


FIG. 10 DEVIATIONS OF MEASUREMENTS FROM VALUES OF HOLBORN AND BAUMANN

cock was then closed and the water remaining in the leads was condensed in the tube B, which was removed and weighed.

For high-temperature regulation a device was constructed utilizing the deflection of a galvanometer in a Wheatstone-bridge circuit, one arm of which consisted of a resistance element immersed in the high-temperature bath. The details of the electrical circuit are shown in Fig. 8. It will be noted that the galvanometer needle was to be used to make electrical contact for operating the sensitive relay R through an electrical amplifier. This method was soon found to be unsatisfactory and was revised to eliminate the mechanical contact.

The needle galvanometer was replaced by a mirror instrument shown at Ga in Fig. 9. A beam of light from the lamp L was reflected from the mirror into the light sensitive cell Se. Changes in the resistance of this cell due to variations in light intensity are caused to operate the sensitive relay Re by means of the electrical circuit shown.

This new apparatus has been in satisfactory operation for some time, controlling the temperature within about 0.02 deg.

Dr. Keyes has described the situation arising with regard to the temperature scale, and unfortunately this last-minute work has interfered with the compilation of our experimental results. A portion only of the vapor-pressure measurements and one or two of the liquid compressibilities have been computed. Table 1

TABLE 1 VAPOR PRESSURE OF WATER

Temperature Deg. fahr.	Temperature Deg. cent.	Pressure (Holborn & Baumann), lb. per sq. in.	Pressure (observed) Lb. per sq. in.		
392	200	225.47	225.55	225.41	225.16
			225.12	225.45	225.64
410	210	276.65	276.48	276.50	276.60
428	220	336.39	336.35	336.31	336.39
446	230	405.67	405.40	405.38	405.54
464	240	485.38	484.97	485.09	485.05
482	250	576.57	576.51	576.53	576.57
500	260	680.43	680.49	680.59	680.62
518	270	797.88	798.11	798.27	798.29
536	280	930.21	930.59	930.32	930.75
554	290	1079.0	1079.4	1079.2	1079.2
572	300	1246.0	1245.6	1245.8	1245.5
			1245.2	1245.6	1245.4
590	310	1431.6	1432.1	1432.3	1432.5
608	320	1637.6	1638.6	1638.5	1634.6
626	330	1866.3	1865.8	1865.9	
644	340	2119.1	2120.3	2120.3	2120.2

gives the values of vapor pressures so far calculated, together with the corresponding pressures of Holborn and Baumann. The individual measurements will be seen to be in accord within about a part in three or four thousand for the most part, and to agree fairly well with the results of Holborn and Baumann.

Due to the uncertainty still remaining in the temperature scale, these results are not given as final, and perhaps they represent the facts in the poorest light.

In Fig. 10 deviations of the separate measurements from the values of Holborn and Baumann are plotted. Deviations are expressed as degrees fahrenheit and are plotted against vapor pressures in pounds per square inch.

With certain exceptions which may be traceable to temperature difficulties, the results seem to have a definite trend with respect to the values of Holborn and Baumann.

As yet the compressibility coefficients for liquid water have been formulated only for 30 deg. cent. and 50 deg. cent.

At 30 deg. cent. and from 100 to 200 atmospheres we obtain a mean coefficient of 43.62×10^{-8} cc. per cc. per atmos. as against 43.6×10^{-8} recorded by Amagat. At 50 deg. cent. and from 100 to 200 atmospheres we obtain 42.54×10^{-8} as against 42.5×10^{-8} given by Amagat.

Notes on the Steam-Research Work Carried Out at Harvard University

BY R. V. KLEINSCHMIDT,[4] CAMBRIDGE, MASS.

IT GIVES me pleasure to be able to present to the Steam Research Committee the final report of our work at Harvard. We hope to be able to publish it in the near future.

There are certain questions that have been raised by Professor Callendar in his recent articles in *World Power*, which I would like to discuss at this time. In particular, he suggests that the question of kinetic energy is not usually given sufficient attention in throttling experiments. I hope to show that in our apparatus any outstanding errors from this source are probably negligible. There are three cases to be considered.

First: Any difference in kinetic energy between the steam at the high-side thermometer and that at the low-side thermometer will directly affect the measured temperature difference. To avoid this source of error, either the velocities of flow at the two thermometers must be the same or the velocity at each place must be so low that the kinetic energy involved is negligible.

[4] Research Fellow, Harvard University.

Second: Callendar calls attention to the fact that any kinetic energy that is generated during the throttling must be converted into heat before the steam passes the low-side thermometer. In the porous plug which we use as a throttle we believe that no high velocities are generated. This opinion is based on the fact that our plugs have from 30 to 40 per cent of their volume void, as determined by filling the pores with water and weighing. If the grains of the plug were spheres in the closest possible piling they would have 14 per cent of voids and minimum free area for flow of 9 per cent. By considering how the ratio of total voids to free-flow area varies as the space between the spheres is increased, we estimate that with 30 per cent voids we might reasonably expect at least 12 per cent of free area, and with 40 per cent at least 20 per cent of free area. As the total inside surface of a plug is about 25 sq. in., the free areas for flow through the plugs will range from 3 to 5 sq. in. The resulting velocities and kinetic energies are very low.

Table 2 gives the kinetic-energy effects at the high-side and low-side thermometers and in the pores of the plug, for the eight worst runs with each of the two plug cases used.

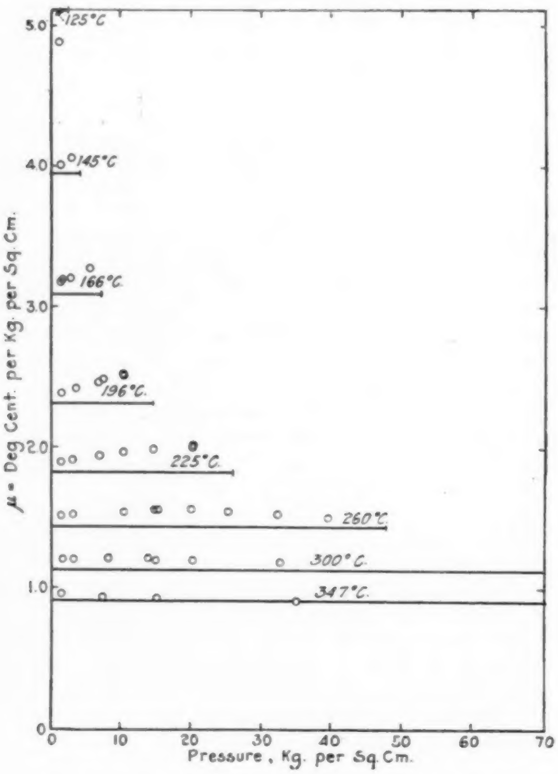


FIG. 11 COMPARISON WITH VALUES USED BY DAVIS (Marks and Davis Steam Tables.)

Third: The possibility of formation of drops of water in the pores of the plug due to the "high velocity generated" is also mentioned by Callendar, but the points that we have taken are never nearer than 10 deg. to saturation temperature, so that the kinetic energy cooling in our case is never enough to even remotely approach saturation. This cannot, therefore, be the explanation of the δ term described in our progress reports and mentioned by Callendar in this connection. This δ term represents a deviation of the product μc_p near saturation from one particular formula-

TABLE 2 COOLING DUE TO KINETIC ENERGY

Run No.	High-side thermometer, deg. cent.	Low-side thermometer, deg. cent.	Net effect, per cent of ΔT	In pores of plug, per cent of ΔT
Old Plug Case				
171	0.0088	0.0038	0.11	0.08
169	0.0057	0.0014	0.12	0.04
158	0.0049	0.0014	0.15	0.06
114	0.0057	0.0017	0.27	0.12
109	0.0021	0.0004	0.16	0.04
123	0.0082	0.0029	0.34	0.20
133	0.0124	0.0063	0.36	0.34
136	0.0021	0.0004	0.24	0.06
New Plug Case				
303	0.0048	0.0048	0.00	0.08
297	0.0055	0.0054	0.01	0.08
266	0.0074	0.0054	0.11	0.10
293	0.0060	0.0059	0.00	0.16
278	0.0028	0.0068	0.08	0.20
282	0.0064	0.0071	0.06	0.18
285	0.0049	0.0041	0.11	0.17
290	0.0055	0.0049	0.07	0.22

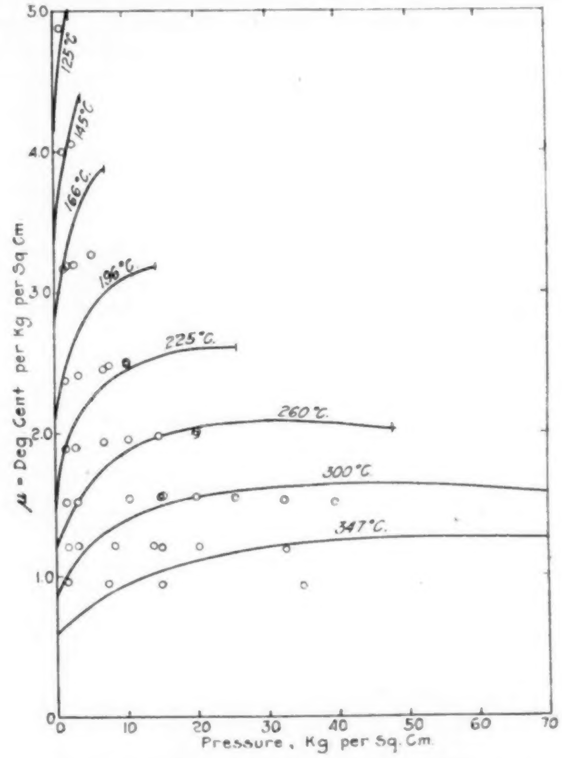


FIG. 12 COMPARISON WITH GOODENOUGH'S EQUATION

FIG. 13 COMPARISON WITH CALLENDAR'S EQUATION (Properties of Steam, 1920.)

tion. The fact that it cannot be due to moisture generated in the plug, as suggested by Callendar, is also obvious when one remembers that our μ's are extrapolated to saturation by very simple formulas without any sign of noticeable anomalies near

saturation, the whole of the δ terms being due to the very rapid change in the other factor c_p near saturation, both as computed by us, and as directly observed by Knoblauch.

In order to compare the results of our work with some of the best-known steam tables and formulas, I have computed the Joule-

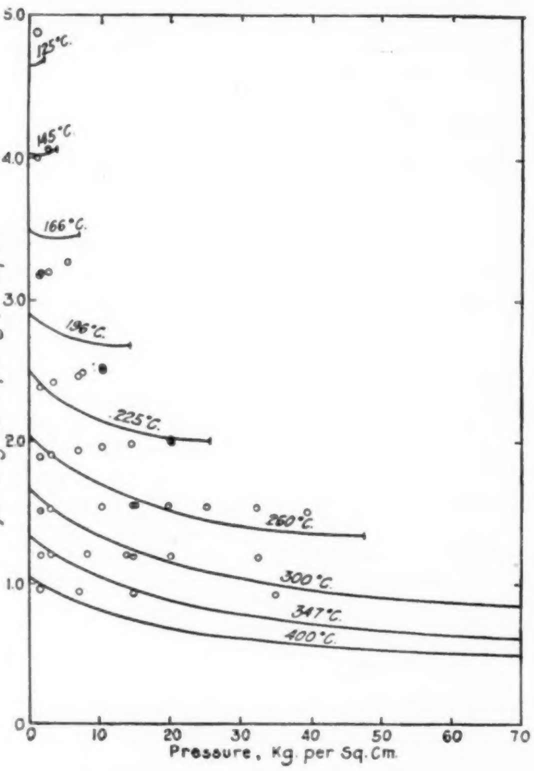


FIG. 14 COMPARISON WITH KNOBLAUCH'S TABLES (Based on measurements of c_p.)

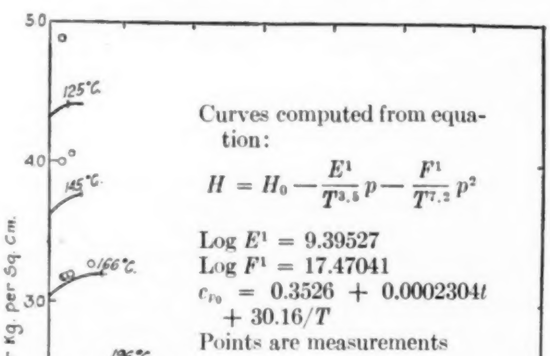


FIG. 15 COMPARISON WITH HECK'S FORMULAS

Thomson coefficients from various equations and plotted them with our observed points in Figs. 11 to 15.

The Joule-Thomson coefficient is very sensitive to slight changes in form or coefficients of the total-heat equation, so that it is not to be expected that values computed from the various steam formulas that have been proposed would agree very well either with each other or with the experimental values. The chief interest in comparing them lies in showing which types of equation give most nearly the proper form of curves, and in showing which of the older steam tables are most consistent with the new data. The wide variety of forms of curve given by the various equations is interesting.

Fig. 11 shows the values used in the Marks and Davis Steam Tables. The agreement is remarkably good. Unfortunately, however, other than Joule-Thomson data were chiefly used in making the tables, so that they are not as good at high pressures as this comparison would indicate.

Fig. 12 is a comparison with Goodenough's equation. It is interesting to note that in spite of the apparently wide divergence in the Joule-Thomson coefficients, a preliminary steam table computed from our results does not differ very greatly from Goodenough's tables. This illustrates the extreme sensitiveness of the Joule-Thomson coefficient as a basis for steam-table computation.

Fig. 13 shows Callendar's equation, the basis of the accepted British steam table. Although predicting the wrong slope and curvature of the lines, so that it cannot be safely extrapolated, his formulation is a reasonably good representation of the properties of steam in the low-pressure region where the throttling experiments on which it was based were made.

Fig. 14 is a comparison with the equations used by Knoblauch to represent the results of the experiments on the specific heat of steam carried on by him and his collaborators at Munich. Davis has found that their observed points show no systematic variation when reduced to zero pressure by the use of our observations, so that the difference between their curves and our points must be looked upon as within the experimental error of their work, and as due to the particular form of equation chosen by them to represent their work.

Fig. 15 is a comparison with Heck's "Steam Formulas" presented at the A.S.M.E. Annual Meeting in 1920. The agreement is strikingly good. It may be noted in closing that any reasonable extrapolation of the Joule-Thomson coefficient as determined by the present investigation could hardly depart from the truth at 1200 lb. per sq. in. by any serious amount because of the very small variation of μ with pressure at the temperatures in question.

The Temperature Scale and the Pressure Standard Employed in the M.I.T. Steam-Research Measurements

BY FREDERICK G. KEYES,[5] CAMBRIDGE, MASS.

DR. L. B. SMITH has already referred to the extreme importance of a reproducible temperature scale. Indeed this problem, among others, connected with our measurements, has kept insistently in the foreground since the beginning. I might state in this connection that during the last dozen years our group at the Research Laboratory of Physical Chemistry has been hoping to make some contribution to assist in improving our knowledge of the relation of the readings of the platinum-resistance thermometer to the absolute scale of temperature.

The difficulties in this problem have centered in part about the quality of the platinum wire whose resistance change with temperature is a function both of the purity of the platinum and the particular construction employed in the mounting, and in part also of the gas-thermometric details which up to the present have not been completely solved.

One gratifying fact has emerged as a result of the work of the Bureau of Standards, as well as others, namely, that the platinum-resistance thermometer when constructed of pure platinum and with attention to certain important details of construction provides a temperature scale which is entirely reproducible. This temperature scale is based on the resistance of the thermometer at the melting point of ice, the boiling point of water at one atmos-

[5] Research Laboratory of Physical Chemistry, Massachusetts Institute of Technology.

phere and the boiling point of sulphur at one atmosphere, interpolation being made by the Callendar formula. This formula is based on a representation of the resistance as a quadratic function of temperature and in the Callendar form exhibited as a rule as follows:

$$t - (\mathrm{pt}) = \delta\left(\frac{t}{100} - 1\right)\frac{t}{100} \quad [1]$$

where t is the true centigrade temperature, (pt) the "platinum temperature," defined as $\frac{100\,(R - R_0)}{R_{100} - R_0}$, wherein R, R_0, and R_{100} are the resistances at any temperature, the freezing point of water, and the normal boiling point of water.

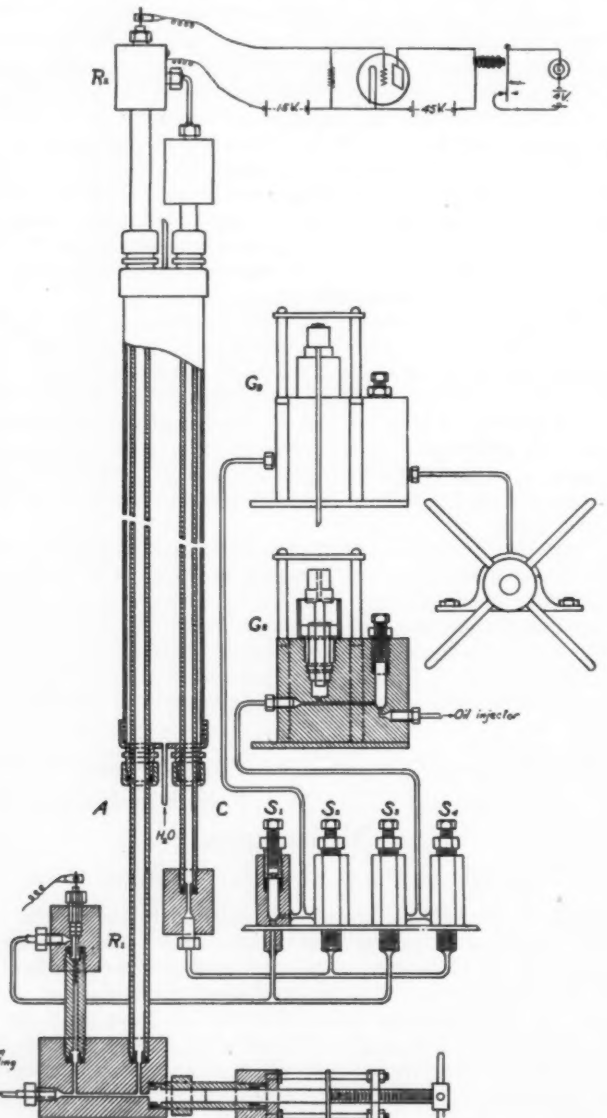


Fig. 16 Pressure-Measuring Device

While it is satisfying to know that we possess a reproducible scale of temperature in the modern platinum-resistance thermometer, we are concerned in the first instance to know the temperature of the three fixed points on the absolute scale. The first two, 0 deg. cent. and 100 deg. cent., are on the latter scale by definition. The sulphur boiling point must be determined and the record of the experimental attempts to locate the boiling point is interwoven very closely with the development of gas thermometers.

At the time (1908) of the original Holborn and Baumann measurements the normal sulphur boiling point was taken to be 445.0 deg. cent. Later gas-thermometric work at the Reichsanstalt indicated that a lower value was more nearly correct and 444.55 deg. cent. was selected. The vapor pressure data recorded for water in the "Wärmetabellen" of Holborn, Scheel, and Henning of 1919 are the previously measured pressures but assigned to temperature recomputed to correspond to a Callendar platinum-resistance-thermometer temperature scale based on sulphur boiling at 444.55 deg cent. in place of the older value, 445.0 deg. cent.

Our own Bureau of Standards has selected for the normal boiling point of sulphur 444.6 deg. cent., which is 0.05 deg. higher than the Reichsanstalt number, and it is this value which we, in our work on the redetermination of the pressure-temperature relation for steam, have employed.

With regard to the quality of platinum in use, it should be stated that some two years ago we gathered all the scrap platinum together which we possessed and the Bureau of Standards was good enough to purify it, returning in wire form sufficient material for about 200 thermometers. We hope the laboratory will be indefinitely provisioned with a uniform grade of platinum. The quality of the wire may be judged by the magnitude of the mean-temperature resistance coefficient taken between 0 deg. cent. and 100 deg. cent. The higher the purity of the platinum the greater this number, which, as determined by us for the Bureau platinum, is about 0.003926, or distinctly higher than for the platinum employed in the thermometers used by Holborn and Baumann.

In brief, then, the scale of temperature which we are using and which will probably be used in the final tables of properties of steam, is that of the purest resistance-thermometer platinum based on the calibration points freezing water, boiling water, and boiling sulphur, the latter being taken as 444.6 deg. cent. N.B.P.

Interpolation is made by means of the standard Callendar formula, and the deviations from the absolute-temperature scale are probably not greater than several hundredths of a degree centigrade at the point of greatest deviation.

The Pressure Standard

The pressure-measuring device used in the present work has been described at our previous meetings, and Dr. Smith has indicated this afternoon again that the floating piston or "deadweight" piston is being used. Since this is in principle a well-known pressure-measuring device, a description will be superfluous.

The problem encountered is to interpret gage indications as a function of the weights used to equilibrate the hydrostatic pressure within the apparatus. Ordinarily the equilibrating weights are assumed to be in direct proportion to the pressure, but experimental proof is lacking at any rate for the gages in use in the steam investigation.

Heretofore in the pressure work of the laboratory a calibration has always been made of the gage directly against a column of mercury. This procedure, while satisfactory in principle, is incomplete, because a column of sufficient length has never been available. The actual column is in fact but 31 ft. in length, and pressure interpretations of the piston gage are obtained by extrapolation, using the proportionality constant obtained from a calibration against the 31-ft. column.

Since a single long column has not been available, use was made of the principle of a scheme which it was proposed to use at the Reichsanstalt. This device was shown to Prof. James A. Beattie, of the Research Laboratory of Physical Chemistry, while he was visiting Dr. Henning.

In this device a mercury column of comparatively short length is used (30 to 40 ft.) and two gages employed, one of which is placed at the top of the column and the other at the lower end. Each gage having been compared with the column with upper end open, the upper gage may be adjusted to a pressure corresponding to one column length. The pressure on the second gage at the lower level of the column will be subjected now to a pressure of two column lengths and its constant thus measured. An interchange of gages will now permit of producing accurately a pressure of two column lengths at the gage and the lower gage calibrated for a pressure of three column lengths. By continuing in this manner a pressure corresponding to as many multiples of the mercury-column length as desired may be obtained.

The Research Laboratory of Physical Chemistry's embodiment of this idea has enabled us to proceed to a pressure corresponding to 600 atmos. or the equivalent of a column 1800 ft. long or about

$^1/_3$ mile. This pressure range will cover all the work which is contemplated on the properties of steam.

The results of the investigation have recently been computed and it has been found that for the form of gage in use the true pressure is proportional to the equilibrating weight to the limit of pressure (600 atmos.) investigated. It is felt, therefore, that the pressure measurements may be looked upon with confidence, and at our next meeting it is hoped we can make a final statement relative to the reliability of the volume measurements.

Progress Made in the Technique of Computing a Steam Table from the Harvard Data

By HARVEY N. DAVIS,[6] CAMBRIDGE, MASS.

THERE are three improvements in the process of computation that have been worked out since the completion of the work reported on by Mr. Keenan. The first is a step-by-step method of numerical integration which takes account of first or second-order differences as may be desired. This will be used in integrating μ to get lines of constant total heat. The second is a similar step-by-step process of a sort essentially equivalent to a differentiation, developed for this work by Prof. O. D. Kellogg, of the Harvard Mathematical Department, which will be used in the preparation of the c_p-ratio chart. It is expected that these processes will be published in one of the mathematical journals in the near future.

The third improvement is a development of an idea suggested by Professor Heck at one of these annual steam conferences, by means of which a simple relation can be established between c_p at zero (or any other) pressure, and the temperature derivative of the total heat of saturated steam. At the higher temperatures, where c_{p0} is fairly well known, this relation gives valuable information about the saturation total heat. On the other hand, at lower temperatures, where the total heat is fairly well known, the relation will, it is hoped, fill an important gap in the c_{p0} curve.

There is a pressing need for additional and more reliable specific-heat data, and it is to be hoped that full details of Callendar's work in England will soon be made available to the public or to the American research group.

It is indeed a source of gratification that Professor Heck is again attacking the formulation problem, so that the research program may be said to be well started on its second phase, in anticipation of the speedy conclusion of the experimental work.

Comparison with the Formulations

By ROBERT C. H. HECK,[7] NEW BRUNSWICK, N. J.

THIS discussion brings into the comparison of present information the Heck formulas of 1920, not heretofore computed. It carries comparisons across more than the range of present data, clears up one major discrepancy in the data, and suggests the first step in a possible new formulation.

At the meeting a set of isotherms of total heat h on pressure p was shown, the Harvard results being represented by curves derived from Davis' original chart of throttling curves (temperature on pressure—Fig. 10, p. 86, Mechanical Engineering, Feb., 1924). That chart, readjusted and extended, now appears as Fig. 2 of Mr. Keenan's paper. The large diagram, with curves at each 10 deg. cent. from 150 to 350 deg., is not reproduced, but is represented by the curves numbered 1 in Fig. 17.

Since the meeting, with the General Electric formulation more fully available, the comparison has been extended to volumetric work and is made also by lines of variation under constant pressure in Figs. 18 and 19. Fig. 18 has heat h for ordinate, but with oblique axes in order to get flatter curves. In Fig. 19 is shown, not the product pv itself, but the difference between ideal RT and actual pv, or the total contractive term X in the general equation

$$pv = RT - X \quad [1]$$

This X is really measured downward, and the scale at the top of Fig. 19 shows how ET varies with temperature t.

[6] Professor of Mechanical Engineering, Harvard University, Mem. A.S.M.E.

[7] Professor of Mechanical Engineering, Rutgers College. Mem. A.S.M.E.

As regards the heat isotherms in Fig. 17, note particularly the reversal in distribution of curvature. In order to give curvature to the isotherm, previous steam formulations have used the parabola with apex and maximum curvature at zero pressure. The plain parabola (on p^2, Heck) is better than the semicubic (on $p^{1.5}$, Goode-

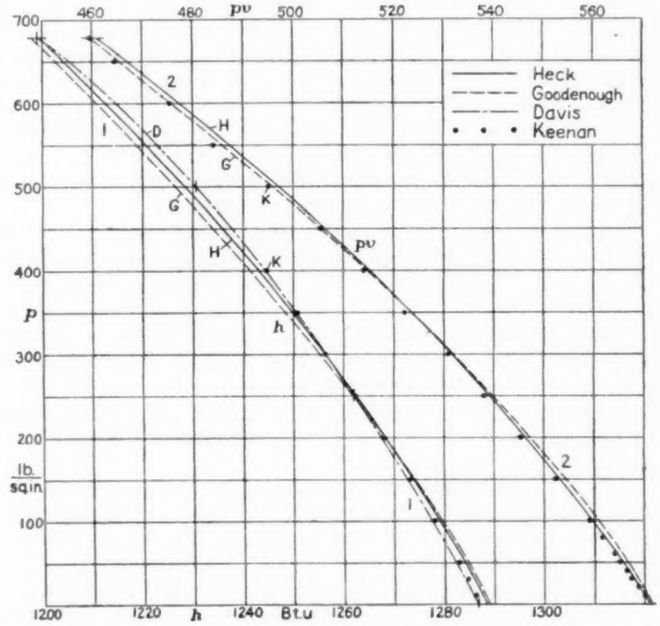


Fig. 17 Isotherms of h and pv on p at 500 Deg. Fahr. or 260 Deg. Cent. (Product pv in lb. per sq. in × cu. ft. per lb.)

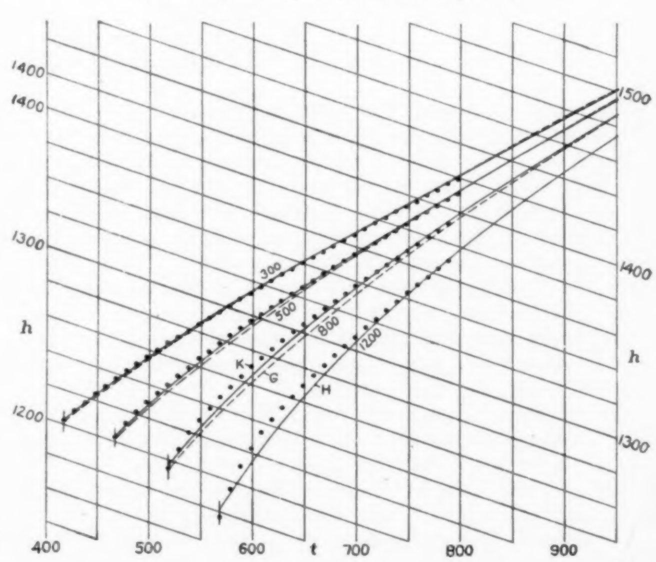


Fig. 18 Lines of Constant-Pressure Variation of Heat h on Temperature t, at Pressures of 300, 500, 800, and 1200 Lb. per Sq. In.

nough), particularly when tested against experimental μ; but both are at fault in straightening out as pressure rises. The throttling experiments show that there should be more curvature at high pressure, and near to saturation, less at low pressure. This is reasonable, because curvature is due to gas imperfection, which is greater at higher densities and near to saturation.

The Davis isotherm in Fig. 17 can be represented with practical precision by a parabola with the apex upward, of the equation

$$h = a - bp + c\sqrt{d - p} \quad [2]$$

Fitted to the cross-marked points at 0, 250, 500, and 679 lb. pressure this equation here became definite as

$$h = 1144.6 - 0.004p + 5\sqrt{810 - p} \quad [3]$$

At the very least, coefficients a, b, c, and d in Eq. [2] must all be functions of T—this in order that h (or v) shall be an explicit

function of T and p. Obviously, then, general equations giving the correct form of isotherm will be harder to manipulate and to valuate than the simpler type heretofore used. Indeed, it remains to be seen whether possible formulas can be based on the idea of Eq. [2].

Increasing curvature near to saturation, with accompanying rapid rise of specific heat, is very evident in the new spot-marked curves of Fig. 18. This change in specific heat will clear up a discrepancy which appears in Figs. 16 and 17 of my Steam Formulas paper [Trans. A.S.M.E., vol. 42 (1920), pp. 741–742]. There the Munich results are compared with computed c_p; and regularly the curves run higher than the points over the range from 50 to 250 deg. of superheat, but near to saturation the points run higher. New curves will keep above the points throughout.

That those experiments consistently run a little low becomes apparent when we try to reduce them to zero pressure (See Davis, MECHANICAL ENGINEERING, Feb., 1924, p. 87, Fig. 12; also Keenan, in this issue, Fig. 4). There, as in my earlier work represented by Fig. 14 of the paper entitled Steam Formulas, a curve that fits the reduced experimental points will give values of h_0 that cannot possibly be correct over the low-temperature range. Conspicuously, Davis' formula for c_{p_0} in the 1924 reference would make h_0 about 6 B.t.u. too big at 32 deg., where the uncertainty of h is of the order of 1 B.t.u.

As to the new volume determinations, represented by curves 2 of Fig. 17 and by Fig. 19, it does not appear that anything wonderful has been accomplished. For one thing, the increased curvature near to saturation has not been carried over from h to pv. Note how the droop below the H-curve, toward 200 deg. of superheat, is greater at 800 lb. than at 1200 lb. in Fig. 19. Certainly, this side of the new formulation is no more than tentative. On the whole, it seems that work upon volume had better wait for the new data on that side. If it were possible, there would be much satisfaction in having the volumetric work carried out to where it would throw light on the big difference between the H- and G-curves at high temperatures, in Fig. 19.

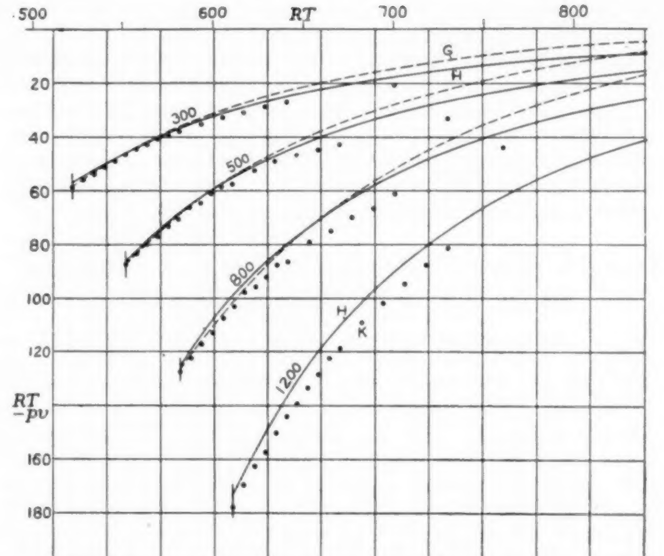


FIG. 19 LINES OF CONSTANT-PRESSURE RELATIONSHIP, REPRESENTING pv ON t

National Research Endowment

THE National Academy of Sciences has appealed to a body of prominent public men to join with leading scientists in an endeavor to secure larger resources for research in pure science. It is hoped that an annual income of at least two million dollars can be secured to establish National Research Professorships and in other ways to coöperate with universities and other institutions throughout the country which are prepared to do their full share in the encouragement and support of fundamental research in the mathematical, physical, and biological sciences. While the United States is in the forefront of industrial research, it is accomplishing much less in pure science than its population and material resources would lead one to expect.

The academy has created a special board of trustees of the National Research Endowment which includes Dr. Albert A. Michelson, president of the National Academy of Sciences; Gano Dunn, chairman of the National Research Council; Dr. Vernon Kellogg, permanent secretary of the National Research Council; Elihu Root, Herbert Hoover, Andrew W. Mellon, Charles E. Hughes, John W. Davis, Julius Rosenwald, Colonel Edward M. House, Cameron Forbes, Felix Warburg, Henry S. Pritchett; Dr. Robert A. Millikan, foreign secretary of the National Academy of Sciences; Dr. John C. Merriam, president of the Carnegie Institution of Washington; Owen D. Young and Henry M. Robinson; Dr. Simon Flexner, director of the Rockefeller Institute for Medical Research; Dr. John J. Carty, vice-president of the American Telephone and Telegraph Company; Dr. William H. Welch, director of the School of Hygiene and Public Health of Johns Hopkins University; Dr. James H. Breasted, director of the Oriental Institute of the University of Chicago; Professor L. R. Jones, of the University of Wisconsin; Professor A. B. Lamb, director of the chemical laboratory of Harvard University; Professor Oswald Veblen, of Princeton University; Dr. Thomas H. Morgan, of Columbia University, and Dr. George E. Hale, of the Mount Wilson Observatory. Mr. Hoover has been requested to act as chairman and has accepted.

Judging from our progress in other fields, we do not lack competent men for research, officials of the academy explain. Too often, with the comfort of their families at heart, such men reluctantly accept well-paid industrial positions instead of poorly paid academic posts. The problem is to make these posts so attractive that the ablest men will seek and hold them permanently because of the opportunities they offer to advance knowledge by fundamental research. This can be done by providing adequate salaries, freedom from too much teaching or administration, necessary instruments and apparatus, and skilled assistants to perform the extensive routine operations that scientific research involves. In short, able investigators should be given some such comfort in life, freedom of action, and opportunity for constructive thought that industrial and administrative officers in this country, certainly of no larger caliber, habitually enjoy. One way to accomplish this is by establishing National Research Professorships, or similar positions, in coöperation with universities vitally interested in the advancement of science.

President Michelson, of the National Academy, in writing to Mr. Hoover to express his great satisfaction that he had undertaken to act as chairman of the trustees of the National Research Endowment, says:

> I regard this as one of the most important and significant movements in the direction of helping to make the contributions to science worthy of the enterprise of America.
>
> We can no longer plead youth and the pressure of building up the industries as an excuse for the unfavorable comparison of our own meager contributions with those of England, France, and Germany. There can be no doubt that the situation would be immensely improved if the prospects of the more promising men who have the talent and ability and the taste for the pursuit of scientific investigation could be made comparable with those of, say, a successful physician or lawyer.

There is not the slightest conflict between the purposes of the National Academy of Sciences and those of the Smithsonian Institution, which is seeking a large endowment fund to provide adequately for the important investigations of its large staff. These two scientific organizations enjoy most cordial relations, as Mr. Hoover indicated in his recent New York address[1] when he strongly commended the efforts of the Smithsonian to obtain an endowment and referred to it as the great pioneer of all American research, which has inspired much of the work in progress to-day. (*Science*, Jan. 1, 1926, p. 10–11.)

[1] MECHANICAL ENGINEERING, January, 1926, p. 6.

SURVEY OF ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

AERONAUTICS

Commercial Aeronautics in Michigan

IT IS STATED that in addition to the Ford Motor Co., two other concerns have inaugurated flying service. The first of these is the Duplex Printing Press Co., Battle Creek, one of the largest manufacturers of printing presses in the country. Starting with one plane during the summer, the company now has two fast planes ready at all times for the transportation of replacement and repair parts needed in emergencies by newspapers. One plane has a capacity of 2000 lb. deadweight. It is stated by I. K. Stone, president of the company, that the extra cost of aircraft transportation is trifling compared with the loss the publisher might suffer by missing one edition or more because of a broken press part. It was due to the great necessity of rapid delivery that this service was inaugurated. The company's special service operates together with the Air Mail wherever possible.

The other company is the Continental Motors Co. of Detroit, which has just announced the purchase of a ten-passenger airplane, designed and built by A. H. J. Fokker. The plane will be used for regular transportation between the Detroit and Muskegon plants of the company and is of the three-engine type. (*The Daily Metal Trade*, vol. 15, no. 238, Dec. 2, 1925, p. 3, *g*)

A Gear-Driven Plane Supercharger

THE supercharger referred to here has been developed by the Engineering Division of the Air Service since 1921. The compressor element is an adaptation of the compressor of the turbo supercharger developed jointly by the Engineering Division and the General Electric Co. (see MECHANICAL ENGINEERING, 1925, no. 4, p. 287). The impeller is made of forged magnesium with deep scallops between the blades, and has a moment of inertia of only 11 lb-in.^{2}

As to lubrication, an oil pump built into the supercharger supplies a gallon of oil a minute in the form of a very fine spray directed against the trailing edge of the pinion and gear. The pinion bearings, gear bearings, and inner impeller bearings are lubricated by the oil mist in the gear case. Tests have shown that the heavier oils worked as well as the lighter oils, but that too much oil caused the bearings to heat.

The oil system was simplified by packing the outer impeller bearings in Tulc, a non-fluid oil. This was renewed every few hours and gave excellent results.

The impeller was driven by a pinion and gear having a ratio of about 13 to 1. The pinion was hollow and was supported on either side by a paired set of Norma L-20 ball bearings. A solid shaft was splined into the pinion and then passed through the hollow impeller shaft to a coupling at the outer end.

The supercharger after a 50-hr. endurance test run on an electric dynamometer at full load was mounted on a Liberty engine, but after 2 $^1/_2$ hr. running the hollow impeller shaft broke. In several other tests, some of them in the air, the solid shafts failed, Liberty engines being used in all cases. With a much greater acceleration and more severe conditions the supercharger ran very well on a Curtiss D-12 engine. From the results of these tests it was decided that the failure on the Liberty engine was due to the torsional vibration of the crankshaft. Former difficulties with timing gear also pointed to this conclusion. Afterward tests were made using different types of solid shafts, and finally a shaft was developed 8 $^1/_2$ by 11 in. and of the largest diameter that would pass through the hollow impeller shaft. The supercharger was operated on the Liberty engine for 28 hr. and a number of test flights were made. It is rated at 20,000 ft., is lighter than the turbo supercharger of similar altitude rating, and offers less head resistance. (David Gregg, Air Service, McCook Field, in *Automotive Industries*, vol. 53, no. 22, Nov. 26, 1925, pp. 906–908, 5 figs., *d*)

AIRCRAFT: (See Internal-Combustion Engineering Evaporative Cooling of Aircraft Engines)

ENGINEERING MATERIALS (See Testing and Measurements: Tests of Airplane and Other Fabrics)

FUELS AND FIRING

The Wuest Oil-Fired Metallurgical Furnace

IN RECENT attempts to improve the quality of cast iron, types of iron have been developed containing moderate proportions of carbon and silicon. It is very difficult, however, to obtain uniform distribution of the graphite in cupola furnaces, especially with small charges, and the present furnace was developed to meet this requirement. The furnace is oil-fired and represents a combination of hearth and shaft types in which the oil consumption was much reduced by the special arrangements made for the circulation of the gases and the preheating of the blast. A one-ton furnace of that kind which has been in use in Germany for more than a year is described and illustrated in the original article. An oil burner is located on the left-hand side of the hearth, which is deepened to form a hollow hearth in the middle portion. Near the other end is a shaft down which the charge works. The shaft is closed below by a door. The flames sweeping over the hearth pass up the shaft from which the fused metal flows, into the hearth, and through a preheater in which the blast is heated to about 400 deg. and temporarily to 600 deg. cent. (752 and 1112 deg. fahr.). The charge is generally mixed with one or two per cent of lime. The addition of coke is unnecessary. It is said that with a total charge of 4000 to 4500 kg. and an average output of 1050 kg. per hr., the oil consumption ranged from 8 per cent to 10.3 per cent reckoned on the charge, which is certainly low. The iron had a melting point of about 1260 deg. cent. (2300 deg. fahr.) and was poured at temperatures between 1500 and 1600 deg. cent. (2912 deg. fahr.). (*Engineering*, vol. 120, no. 3125, Nov. 20, 1925, pp. 653, *d*)

Low-Temperature Carbonization as a Commercial Process

A DISCUSSION of the probable market for the smokeless fuel, high-heat-value gas, and tar oils produced. The author comes to the conclusion that the low-temperature oils have still to find and develop a market in order that their best value may be realized. It is possible that the low-boiling fraction can equally be made available as motor fuel, leaving for the remaining fraction only the low-priced fuel-oil market until investigation and experiment have demonstrated their real worth and proper place. Several processes operating on a semi-commercial scale appear to have recovered quantities from 30 to 40 gal. per short ton of coal. Careful work by the U. S. Bureau of Mines shows that from standard Pittsburgh coal yields amounting to 32.5 gal. of dehydrated oil and 3.2 gal. of light oil may be expected. The yield of gas from true low-temperature distillation is said to be much lower than from high-temperature operation. Probably the figure from representative coals would be about 3500 cu. ft. per ton, and the calorific value is generally very much higher than that made in high-temperature processes. J. D. Davis in his work for the Bureau of Mines obtained yields from Pittsburgh coal of from 3400 to 7175 cu. ft. per ton, depending on the temperature used, with a heating value of about 680 B.t.u. per cu. ft. The most efficient utilization of this gas of a relatively very high heating value has not yet been worked out. The growing tendency to employ gas of lower heating value for domestic use is not favorable to the realization of the fuel value of this rich gas except in special cases.

The yield of ammonia in all low-temperature operations is small, at times too little to justify the expense of recovery. On the other

hand, there is apparently a ready market for low-temperature coke as the public is demanding more than ever before a smokeless domestic fuel which is easy of ignition and which can be produced at a cost not greatly above that of bituminous coal. A method of low-temperature distillation of coal should have wide field as soon as plants of relatively small capacity can be economically installed and operated so that they may be available for supplying a desirable smokeless fuel in small localities. Moreover they should be simple to operate as they have not the diversity of by-products such as are obtained from a by-product coke-oven plant. It would appear that a simple treatment of the oil, which is practically the only by-product, will make it available in many local markets. (Wm. Hutton Blauvelt in *Chemical and Metallurgical Engineering*, vol. 32, no. 18, Dec., 1925, pp. 925–927, *g*)

Coal Distillation at the Mathias Stinnes Colliery

Description of an installation located in Karnap, near Essen, and built by the German Coal Separator Co. The plant has been in operation since April, 1924.

The difficulties arising from stresses in the drum have been overcome by having two drums, one within the other. The inner drum, which also serves as a supporting frame, is fed with fresh coal at the lower inclined end (Fig. 1). The coal is moved upward by means of a conveyor worm in such a manner that the temperature should not exceed 390 deg. fahr. at the upper exit, a temperature which does not affect the the strength of the drum. At the same time the cold coals are preheated and dried without, however, any caking or swelling taking place. The coals then drop into the outer drum through openings at the top end of the inner drum. In the outer drum they move downward owing to the drums' rotation and inclination, and are distilled on the way. At the bottom end the distilled coal leaves the drum in the shape of semi-coke, the volatile products being sucked off at the upper end of the drum. With this arrangement there is neither condensation on the cold fresh coals nor superheating at the discharge end of the drum.

What is claimed to be an important innovation consists in superheated steam being blown into the casing drum at the upper end of the exhaust-connection piece, thus preventing premature deposition of tar components boiling at high temperatures. The steam provided is exhaust from the driving machines. This arrangement has given excellent satisfaction as regards control of caking and swelling coals. The drum heating is by means of a circulating system. The hot combustion gases from the gas heating working with the most favorable excess supply of air are mixed with the hot waste gases possessing a temperature of about 570 deg. fahr. and are circulated by a ventilator at the foot of the smokestack. This arrangement not only leads to a considerable saving of heat, but also affords the possibility of constantly maintaining the heating temperature with a CO_2 content of 16 per cent in the waste gases.

In the cooling of the hot semi-coke the dry cooling system is used separately for coarse and fine coke. The coarse coke is cooled with the aid of indifferent gases which are subsequently recooled in dripping coolers. The fine coke is cooled by self-extinction and by ventilating tubes arranged in the bunker. The advantages of dry cooling come into evidence when grinding and burning the semi-coke.

It is noted expressly that caking and swelling coal could be distilled in large quantities and in continuous working in the above plant—apparently for the first time. In judging the results it should be remembered that the coal handled in itself only contains 5.8 per cent of bitumen and can therefore scarcely be termed rich. The plant dealt with 60 to 80 tons of dust coal in 24 hr., the dust coal being obtained from the coal-dressing plant of the colliery by dry suction. In distilling this dust, which has a fineness of 35 per cent residue on an 80-mesh sieve and 75 per cent residue on a 178-mesh sieve, the following average figures of production were ascertained: Semi-coke, 82 per cent; primary tar, free from water content, i.e., 87 per cent of the quantity theoretically available, of which 0.8 per cent is gasoline, 75.05 per cent; gaseous gasoline, 0.43 per cent; viscid tar, 0.48 per cent; distillation gas per 1 ton, 2500 cu. ft.—all data referring to dry coke. Five per cent of steam and 10 per cent of fine semi-coke were added and the speed of rotation was 90 sec. per revolution of the drum; the charge remains in the drum for about $2^1/_2$ hr. Loosely heaped, the height of dry-cooled semi-coke from dust coal amounts to 25 lb. per cu. ft. for coarse coke and 38 lb. per cu. ft. for fine coke, which means a very considerable improvement in the density of the semi-coke when compared with the figures for semi-coke resulting from other processes. The semi-coke obtained from the above-mentioned dust coal is well caked, comparatively hard, and contains about 70 per cent of coarse coke in the case of dry cooling, instead of but 58 per cent with piece sizes between $^3/_8$ in. and $3^5/_8$ in. in the case of wet quenching. The semi-coke will be the more brittle and lighter the more steam is introduced, and the harder and denser if not more than 10 per cent of fine semi-coke is added and if the state of softening of the particles of coal is rapidly passed in a short zone. The lowest limit of its calorific value was determined as 10,560 B.t.u. per lb. while the lowest calorific value of damp dust coal amounted to 11,600 B.t.u. per lb.

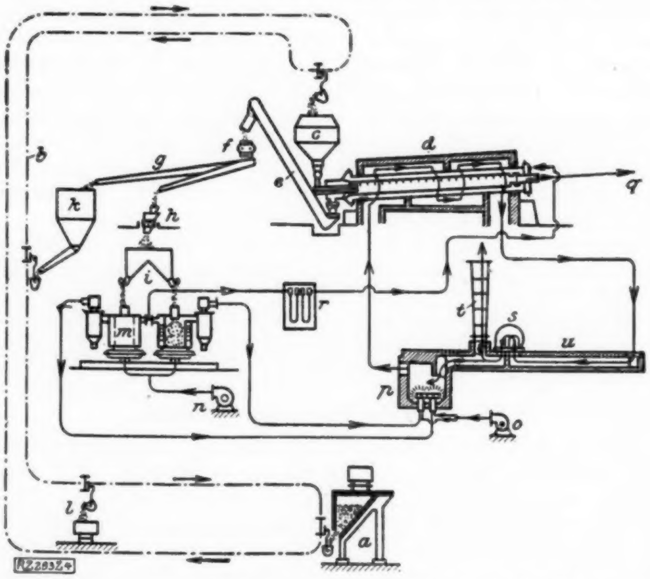


Fig. 1 Working Process of the Coal-Distillation Plant at the Mathias Stinnes Colliery in Karnap, Rheinland

(*a*, Coal bunker under the railway line; *b*, aerial ropeway; *c*, coal bunker above the distillation furnace; *d*, distillation furnace with distillation drum; *e*, bucket elevator for semi-coke; *f*, semi-coke crusher; *g*, shaking chutes; *h*, semi-coke weighing machine; *i*, semi-coke bunker above the gas producer; *k*, bunker for excess semi-coke; *l*, semi-coke removal; *m*, gas producer with steam generators; *n*, ventilator; *o*, blower supplying combustion air; *p*, combustion chamber; *q*, distillation-gas conduit to condenser; *r*, steam superheater; *s*, circulating ventilator; *t*, smokestack; *u*, circulation duct.)

The semi-coke produced has met with general approval for domestic purposes in the vicinity of the distilling plant; it was found by experiments to be almost equivalent to anthracite when burnt in slow-burning furnaces and stoves. Stoves stoked with semi-coke only require looking after a little more frequently than when burning anthracite, while on the other hand semi-coke works out much cheaper. Semi-coke is moreover highly suitable for gasification in producers. The comparatively high contents of ashes do not disturb at all, as the slags produced rub down very easily. The calorific value of the producer gas from semi-coke is about 146 B.t.u. per cu. ft. About 7 tons of the coke are handled per 24 hr. in a water-jacketed producer of 8.2 ft. diameter.

For coal-dust furnaces fine semi-coke can be used without further preparation as it is dry, but its grinding requires more power than coal; on the other hand, no troubles are experienced in working. It is advisable to let the semi-coke still contain 15 per cent of volatile components for this purpose. Special attention is called to the experiments and tests carried out in the foundry of the Mathias Stinnes colliery, which proved that the semi-coke produced in the distillation plant could well be mixed with the foundry coke. This represents a wholly new possibility of application; hitherto it has generally been believed that semi-coke was absolutely useless for smelting purposes owing to its rubbing down so easily and because of its low specific gravity. The charge hitherto customary consisting of 660 lb. of pig iron and scrap and 54 lb. of foundry coke, or roughly 8 per cent of fuel, could be replaced by a charge comprising the same quantity of iron with 15.5 lb. of coke and 24.3 lb. of semi-coke, i.e., 6 per cent of fuel only, the molten metal simultaneously being

improved. In other words, the saving in fuel amounted to 25 per cent. A slight improvement was also ascertained as regards the sulphur content. Endeavors to smelt with semi-coke alone have hitherto remained unsuccessful. Semi-coke in pieces can also be used as a substitute for forge coals; it is particularly suitable for bending tubes as it has a higher combustion temperature.

The primary tar obtained is said to be good in every respect. The dust content is much less than with tar obtained from coking. The latter may contain 3 to 8 per cent of matters not soluble in benzol, whereas the Karnap crude primary tar in continuous working only shows an average dust content of between 0.5 and 2.5 per cent. The separation of dust and water is easily effected. Apart from its high calorific value, the crude tar also furnishes a very good return of oil, amounting to 65 per cent. Attempts to utilize gasoline from primary tar and primary gas for motor-car engines have given full satisfaction. After having been freed of gasoline the distillation gas on an average shows an upper calorific value of 730 to 840 B.t.u. per cu. ft. and its density averages between 0.75 and 0.78 as referred to air; owing to its superior quality it is used in supplying gas over long distances. It may also prove valuable for increasing the heating capacity of inferior gases with which it is mixed. The distillation plant for stoking consumes about 6.3 to 6.9 per cent of the quantity handled if 73 tons of dust coal of natural moisture are dealt with per day. The higher figure refers to the net quantity of coal handled, without including the additional 10 per cent of fine semi-coke.

It is evident from the above that numerous different influences render careful examination of the economy of distillation necessary in each separate instance. Apart from the price for raw coal and the prices that can be obtained for the finished products, the economy of the plant is chiefly determined by the quality handled and the uniform working of the plant. For instance, in the case of a plant working with one drum and assuming the price of coal dust at 9.8 shillings per ton and a selling price of 2.2 shillings per 100 lb. for crude primary tar, the plant will begin to work economically if 50 tons are handled in 24 hr. (G. Cantieny in *Engineering Progress*, vol. 6, no. 11, Nov., 1925, pp. 349–352, 4 figs., *d*)

Pulverized-Fuel Firing

In the course of an extended paper read before the Institute of Marine Engineers the author touches on many aspects of the fuel problem, among which are the following.

Colloidal Fuel. There are possibilities for pulverized fuel for marine work by mixing it with thick fuel oil to form what is known as colloidal fuel. Experience with such fuel with land plants has shown that if the pulverized fuel does not exceed 40 per cent of the mixture, there is little tendency for it to separate out. By reason of the fact that coal is a much cheaper fuel, reckoned on a B.t.u. basis, a colloidal mixture is cheaper than oil alone.

During the last big coal strike, colloidal fuel was tried in various places, including for locomotives by the Great Central Railway, and it was found possible to use it in burners in much the same way as oil; and to store it without risk of oxidation or spontaneous combustion. Because of greater viscosity, the mixture is not so liable to leak from tanks as ordinary oil, and as it can be stored easily there is no reason why the present oil stations should not be fitted with pulverizing plants, and supply a colloidal mixture in place of oil.

Refuse Fuel. For many years it has been the practice to tip refuse fuel at collieries, and as a consequence there are millions of tons of fuel waiting to be used, particularly in old colliery districts such as South Staffordshire.

At the Nechells power station, Birmingham, fuel from the pit heaps is being burnt which contains below 9000 B.t.u. and up to 20 per cent of ash, and costs only about seven shillings a ton delivered.

Largely because of the possibility of burning such low-grade fuel in a complete way without causing a nuisance, four boilers in that particular station have been equipped for pulverized-fuel firing, and an order given for equipping more boilers.

At the Philadelphia power station in Durham, a waste material called "splints" containing up to 30 per cent of ash is burnt in pulverized form in a boiler that was changed over from mechanical stoker firing, and the engineer in charge says he is very satisfied with its performance.

When coal is undercut by machines the percentage of cuttings to the total coal cut depends on the depth of the seam and whether the cut is made in the coal or in a band of shale; e.g., in a seam of coal 40 in. thick, if the undercut is in the coal and 4 in. deep, then the amount of cuttings is above 10 per cent.

By bringing the cuttings out of the mines the workings are made much safer, and less stone dusting is required to make the fine dust that remains in the workings non-explosive.

The Pelton Colliery Company, Ltd., has recently applied turbo-pulverizers to five boilers in order to burn cuttings, etc., which contain 10 to 20 per cent of ash and 30 to 50 per cent of carbon, and have calorific values ranging from 8000 to 12,000 B.t.u.

When the cuttings arrive at the surface they are fed through sheet-iron chutes to turbo-type pulverizers which are fitted with a series of disks having flat-faced manganese-steel beaters, each pulverizer having a capacity of 1400 lb. of coal per hr. and being driven at 1750 r.p.m. by a 25-hp. three-phase motor.

A fan propels the powdered fuel through a 6-in. galvanized -iron pipe to the combustion chambers of the boilers, two of which evaporate 15,000 lb. of water per hr., and three 8000 lb. per hour.

For the three 8000-lb. boilers, the combustion chambers have been increased by 533 cu. ft. and for the two 15,000-lb. boilers, by 1040 cu. ft., and the extra brickwork has been strengthened by channel girders, and the sides of the furnace encased by steel plates.

The boilers were originally fired with coke-oven gas, the steam pressure being 80 lb. per sq. in., and when the coke ovens were discontinued, they were hand-fired for a time. The pressure is now 120 lb. per sq. in. with pulverized fuel.

With hand firing the best unscreened coal was used having a calorific value of 12,000 B.t.u.; but with pulverized-coal firing the coal-cutter cuttings have an average value of 10,500 B.t.u. and yet give a higher evaporation.

Higher Refractories. One direction in which a reduction in furnace size may be looked for is in the production of refractories to withstand much higher temperatures than those which are at present on the market, while at the same time not costing much more.

It is possible, of course, to make very highly refractory materials by calcining and sintering at high gas temperatures and especially by treatment in electric furnaces, but refractories thus made are too expensive for boiler furnaces.

Refractories which give considerable promise are those which contain sillimanite, this being the name of a natural aluminium silicate ($Al_2O_3Si_2O_5$) found in India and elsewhere. It is successful for refractory bricks because it is neutral, and therefore practically unaffected by either acid or basic slags.

In the *Journal of the Society of Chemical Industry*, A. F. Greaves-Walker describes the properties of sillimanite, and claims that it can be used up to temperatures near its melting point, that it maintains constant temperatures, and that spalling is hardly present owing to its low coefficient of expansion; also that if properly burnt it is impervious to slags and metals.

Swan, Ratcliffe & Co. make bricks which contain about 30 per cent of sillimanite and sell them under the trade name of "Leolite," and they are said to be able to withstand temperatures up to 1800 deg. cent.

The principal argument in favor of spending money on highly refractory bricks, able to withstand very high temperatures, is that the relatively small chamber which results is quickly built and, what is very important, the bricks can be quickly renewed.

The problem as regards refractories can be briefly stated in the following way—whether it is better (*a*) to build a small chamber with 4000 highly refractory bricks at £50 a thousand in, say, one week, or (*b*) to build a larger rectangular combustion chamber with, say, 40,000 firebricks costing, say, £10 a thousand, which may take weeks to build.

There is no doubt that as the prices of the higher refractories come down, more of them will be used for pulverized-fuel furnaces, and as a result the sizes of all furnaces can be reduced; but it must be remembered that there is a minimum, because length of flame is highly important, and the greater the mass of incandescent particles, the greater the radiation effect.

The above points are especially mentioned because size of combustion chamber is the most important factor when considering the possibilities of applying pulverized fuel to marine work.

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The machine is made in two sizes, 8 ft. and 10 ft. in diameter inside the brick lining. The oscillating water-cooled mechanical poker extending from the top down into the fuel and combustion zones is at work all the time, and its influence is felt down to the bottom of the fire. It is inclined at an angle to the vertical, oscillating in a path which forms the frustum of a cone, and is mounted in a large circular bearing. It has in its travel an upward and downward swing from the center of the producer to the brick lining of the shell and backward. These combined actions keep the fuel free and loose and have other advantages. The bearing sleeve of the poker has a segmental gear on one side which meshes with a similar gear oscillating loose on a vertical shaft. The gear is driven through a "shear pin" connection with a crank connected on the vertical shaft. In case of any unusual resistance being encountered by the poker, this pin will release the drive and it can readily be replaced. The ashes are assisted in their descent from the combustion zone by the down stroke of the poker, the combined action of the hexagonal hood (a casing having conical sides from under which the blast passes from the central duct into the ash zone; it is equipped with ribs on each upper surface), and the intermittent rotation of the ashpan. This action also has the effect of crushing the clinkers that may be formed. (*The Iron and Coal Trades Review*, vol. 111, no. 3011, Nov. 13, 1925, pp. 778–779, 3 figs., *d*)

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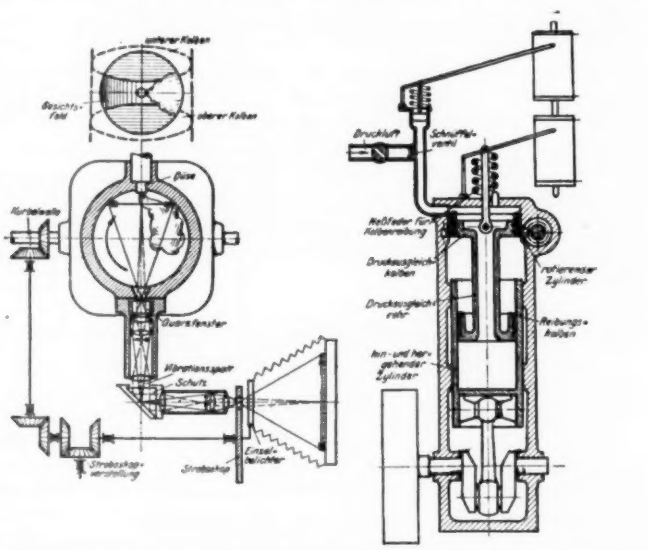

Fig. 2 Testing Devices for Oil Engines—Left, Apparatus for Observation of Flame of Combustion in the Cylinder; Right, Device for Measuring Piston-Ring Friction

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In the actual wire on switching on the 12-volt current the heating unit reaches a steady temperature of 1000 deg. cent. (1832 deg. fahr.) in about 15 sec. and the resistance unit a temperature of 200 deg. cent. (392 deg. fahr.). If now the engine is started up and ignition occurs, the temperature of the combustion chamber will rise to, say, a mean temperature of 500 deg. cent. (932 deg. fahr.). Under these conditions the resistance unit will rise to a temperature of 600 deg. cent. and owing to its increase of resistance will automatically cut down the current from 12 amperes to 9 amperes, with the result that the heating unit reaches a tempera-

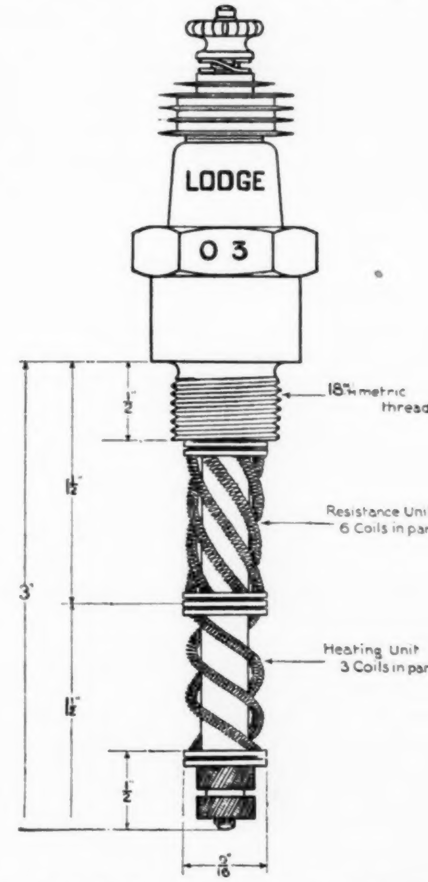

Fig. 3 Lodge Hot-Wire Ignition Plug for Starting Semi-Diesel Engines

ture of only about 1300 deg. cent. Under such conditions of maximum temperature the heating unit may be expected to have a long life.

The electrical gear consists of a dynamo driven from the engine, or 12-volt storage battery, and a switchboard carrying an automatic charging switch. (*Gas and Oil Power*, vol. 21, no. 243, Dec. 3, 925, pp. 61–62, 3 figs., *d*)

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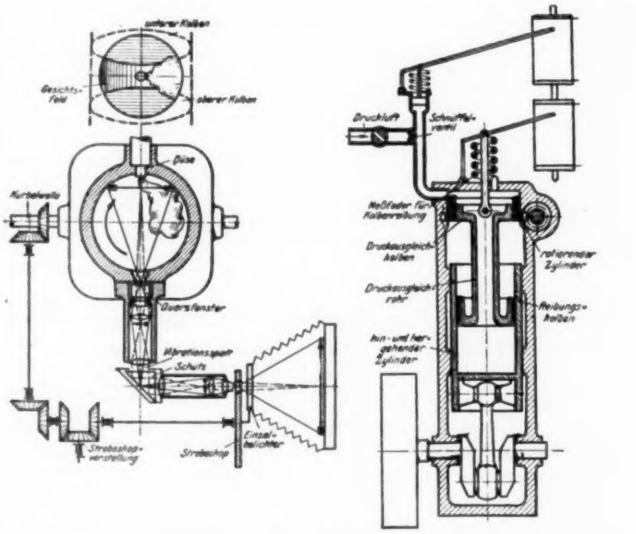

FIG. 2 TESTING DEVICES FOR OIL ENGINES—LEFT, APPARATUS FOR OBSERVATION OF FLAME OF COMBUSTION IN THE CYLINDER; RIGHT, DEVICE FOR MEASURING PISTON-RING FRICTION

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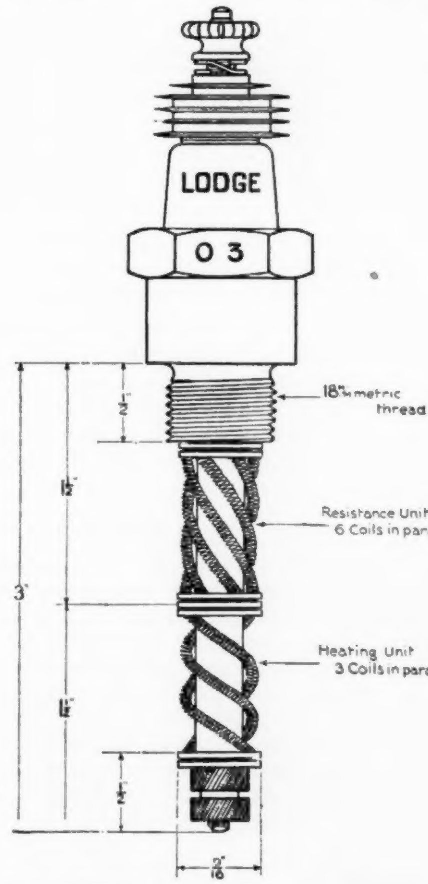

FIG. 3 LODGE HOT-WIRE IGNITION PLUG FOR STARTING SEMI-DIESEL ENGINES

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entirely omitted, changing of gear being effected merely by an oil-distributing cock. The wheels for the various speeds are engaged and disengaged by means of friction disks located inside the gear wheels, oil under pressure being used as a controlling means when engaging and disengaging the friction disks.

The principle and method of operation will be understood by reference to Fig. 4. The toothed wheel *d*, consisting of two parts, runs loose on the collars of the two friction disks, which by means of grooves cause the coupling shaft *a* to rotate, and can be moved thereon in an axial direction. When the coupling is being engaged, oil under pressure is led between the coupling disks through the port *c* of the shaft *a*; the coupling disks are thus pressed against the rotating toothed wheel *d*, and commence to rotate with these. When disengaging a wheel, the oil under pressure contained in the space between the friction disks is led away and the disks are

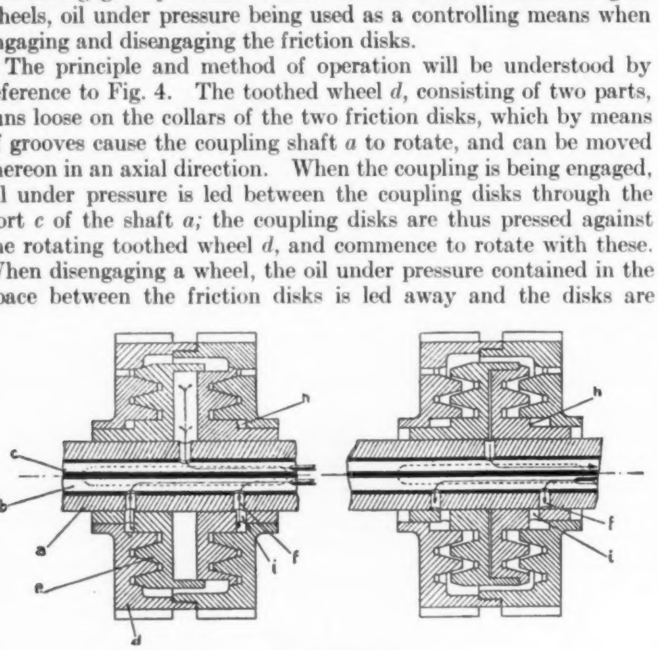

Fig. 4 The S.L.M. Gear
(Left, coupling engaged; right, coupling disengaged.)

moved against each other by the pressure in the chambers *h*, into which oil under pressure is continually fed through the port *b* and the bores *f* and *i*. When one speed is being engaged, the previous speed is simultaneously and automatically disengaged. Therefore it cannot happen that two speeds are engaged simultaneously. (*The Iron and Coal Trades Review*, vol. 110, no. 3011, Nov. 13, 1925, pp. 780, 1 fig., *d*)

Toothed Profiles with Reference to the Path of Contact

The author studies mathematically the form of a toothed profile whose path of contact is a conic curve, and derives various forms of profile as special cases. First the profile of an elliptical path of contact is obtained, and as its special cases the profiles in hyperbolic, parabolic, circular, and straight paths of contact are derived. Next the inverse curve of a conic section with respect to a focus or the limaçon is taken as a path of contact, and profiles such as a circle, a straight line, etc., are derived by changing the form of the limaçon. (Masao Naruse in *Technology Reports of the Tohoku Imperial University*, Sendai, Japan, vol. 5, no. 3, 1925, pp. 169–184, 28 figs., *m*)

MACHINE SHOP

Fits of Shafts and Holes

When fixed gages are used there is said to be a tendency to bunch the finished sizes nearer the "go" than the "not go" extremes, and this applies to any type of gage unless the users are very skilful. It is natural for operators to play for safety; they endeavor to leave as much material on as possible, yet to keep within the limits. Fixed gages have the defect of not indicating definite sizes; they show that the work is within or outside the limits, but not by how much. Hence diameters are made as far as may be from the "not go" sizes, for a little more material can always be removed, but none can be added; and when the "go" end of the gage will pass, why should extra time be spent in aiming at the mean or the ideal size?

Then there is a difference in "feel" with gages. As a general rule, the higher the skill in gaging, the larger will a shaft appear to be and the smaller a hole. Thus, if the ends of a snap gage measure 0.749 and 0.750 in., the average operator is likely to pass the larger end over a shaft measuring 0.7502 in. without noticing the strain; and, similarly, he will force the small end over 0.7492 and believe the work to be right down to the limit. Actually, therefore, from his clumsy feel and fear of taking too much metal off, the real mean size of the gage as he uses it is 0.7497, and not 0.7495 in. Although a plug gage will not spring, the same man will use more force in using the "go" end than an inspector, whose feel is more cultivated.

Besides these factors, it must be taken into consideration that work which is truly round and parallel is extremely difficult to produce. Even high-grade commercial plug gages are rarely near to perfection, so more ordinary work is commonly very imperfect. With shafts and holes alike the operator endeavors to finish so that no part shall pass the "not go" gage, and this tends to increase the means size of shafts and reduce the diameters of holes. As a rule, holes are bell-mouthed, and, since it is desired that even the mouth shall not admit the "not go" plug, the greater part of the length of a hole is smaller than it would be if it were parallel. In the writer's experience the actual resulting mean sizes for tolerances of between 0.001 and 0.004 in. are bunched about one-third of the distance between the extreme and nearer the "go" sizes; that is, a shaft desired to be between 1 and 1.003 is likely to be, on the average, 1.002 in. And those larger and smaller will not be distributed evenly; about half will be very close to the 0.002 size, a quarter will be definitely above it, and the rest, while distributed below, will be—most of them—above 1.001. But, of course, a good deal depends on the process and other circumstances. [Abstracted from an editorial published in *Machinery* (London), vol. 27, no. 689, Dec. 10, 1925, pp. 328, *p*]

MOTOR-CAR ENGINEERING (See also Machine Parts: The S.L.M. Speed-Change Gear)

Supercharging

In an editorial *The Automotive Engineer*, a British publication, expresses the view that the recent London automobile show would indicate that the possibilities of supercharging ever becoming a generally commercial proposition for automobiles are rather remote. It is true that the mechanical difficulties involved in the application of supercharging are not serious. The question, however, inevitably involved is whether or not the scheme provides a commercial return for the extra expenditure and the additional complication. For racing, supercharging offers distinct advantages, while on aircraft engines it is practically indispensable; but on automobiles the situation is different. Even today it would be quite possible to produce on a commercial basis gasoline engines with appreciably greater horsepower per unit capacity than the average engine of the present day. This can be done without supercharging merely by increasing compression and designing for more revolutions per minute. Designers are quite capable of doing this, particularly if assisted by the fuel chemists, who could, if necessary, raise the detonation point. When maximum output per unit of capacity is reached and still higher power is required, supercharging will be one of the possible alternatives. (*The Automobile Engineer*, vol. 15, no. 209, November, 1925 p. 395, *g*)

PHYSICS

The Motion of an Air Bubble Rising in Water

Air bubbles are formed in water naturally or artificially. Thus, in a water turbine or a pump, atmospheric air naturally mixed with water expands to form large bubbles in the space where the pressure is very low, as in the draft or suction tube, which destroys the effective action of the machine. In the air-lift pump, air is purposely forced into the water deep in a well to make it form bubbles rising in the eduction pipe, and their sizes and forms affect greatly the action of the pump.

The forces acting on an air bubble rising in water may be classified as the surface tension, the upward force due to buoyancy, and the resistance to motion offered by the surrounding water.

The surface tension acts to keep the bubble spherical, this being its most stable form, while the resistance causes it to deform to a flattened shape.

The smaller the bubble and the larger the effect of surface tension to keep it spherical becomes in comparison with the resistance,

the more it resembles a true spherical shape and the more stable it is. When the bubble is large the effect of the surface tension is small compared with the resistance and it displays some peculiarly flattened outline which is very unstable, changing its shape momentarily with some oscillating features.

A very small bubble, therefore, may be regarded approximately as a sphere, and, with some suitable assumptions, its motion may be treated mathematically; but for a large bubble such as is common in practical cases the simple mathematical treatments cannot be applied to solve even approximately its motion in water.

The object of the present investigation was to study the motion of a bubble in water and find the law of resistance governing it. In the case of one of a particular size, the author arrived, among other things, at the following conclusions:

1 When an air bubble rises from rest in still water it attains a constant terminal velocity almost as soon as it has started. (The critical position at which the terminal velocity is attained is about 3 to 4 cm. above the air nozzle.)

2 The terminal velocity is maximum for a bubble whose radius is equal to the critical radius. (The critical radius is about 0.165 cm. and its terminal velocity is about 27.8 cm. per sec.)

3 For bubbles smaller than the critical radius the terminal velocities increase approximately linearly with their sizes.

4 For bubbles larger than the critical radius the terminal velocities increase nearly parabolically with their sizes, and tend to become constant irrespective of their sizes. (The constant velocity is about 23 cm. per sec.)

5 The rate of resistance suddenly increases at the critical radius, and the shape and the course of the bubble become unstable at that point.

6 The bubble traces a kind of a helical course on its upward motion and displays a flattened outline, the major axis of which lies perpendicular to its course.

7 The ratio of the mass of water carried up with a passing bubble to that displaced by it is proportional to the square of its radius or to its surface area.

8 The resistance to motion of a bubble is proportional to the cube of its radius or to its volume.

An equation of motion was derived for the upward motion of the bubble and the terminal velocity of a bubble, the radius of which is known, has been determined. (Otogoro Miyagi in *Technology, Reports of the Tohoku Imperial University*, Sendai, Japan, vol. 5, no. 3, 1925, pp. 135–167 and 5 plates of illustrations, *e*)

POWER-PLANT ENGINEERING

Pitting and Corrosion in Boiler Flues

THE *Railway Review*, published in Chicago, Ill., offers a prize of $1000 for the best answer to the question, "How to Stop Pitting and Corrosion of Locomotive Boiler Flues, Shells and Fireboxes." This offer is made only to subscribers to the *Railway Review* who, on or before March 30, 1926, submit in written form the best answer to the above question. (*Railway Review*, vol. 77, no. 23, Dec. 5, 1925, pp. 833–834, *g*)

A New Steam Generator

WHAT is regarded as a revolutionary development in steam generation for power purposes is a new steam generator which, in an installation in the plant of Taylor Brothers & Co., Ltd. in England, gave over 70,000 lb. of steam per hour from 2000 sq. ft. of heating surface. This corresponds to 35 lb. of steam per sq. ft. The development is one of the Combustion Engineering Corporation, New York, and comprehends the burning of pulverized coal under extremely high-temperature conditions.

The combustion chamber may be described as amounting to a rectangular box on end with the sides of the box made up of boiler tubes. The spaces between the tubes have fins, or extended surfaces, to secure an airtight inclosure. The pulverized-coal burners are in the upper levels and in the corners of the box. The air delivered to the burners reaches them at an unusually high temperature for such practice, coming from an air preheater designed for the purpose. The main volume of supplementary air is forced downward through the chamber and the resulting gases, usually high in temperature as stated, have a vortical action and pass rapidly downward into a settling chamber, so-called. The bottom of the combustion chamber is made up of plain boiler tubes, in a bank several tubes deep and spaced across the chamber bottom between water drums on the two opposite sides of the boiler. The plain spaced tubes allow for the free passage of the gases into the settling chamber. All water-circulating arrangements are outside of the tube chamber.

The gases on reaching the settling chamber pass quickly to a steam superheater and thence through the air heater for the burners. The air heater, of course, works on the exchange principle of taking from the products of combustion the heat utilized for the preheating. (*The Iron Age*, vol. 116, no. 25, Dec. 17, 1925, pp. 1707, *d*)

The Exhaust-Gas Turbine

IT IS suggested that an exhaust-gas turbine something along the lines of that used by Professor Rateau for supercharging on airplanes might be used on shipboard. The increase of pressure which is given by this type of turbine is not very great, but it might be economically utilized for scavenging purposes where the two-stroke-cycle engine is employed, raising the pressure in the scavenging pump from atmospheric to 2 or 3 lb. per sq. in. above it. Where the four-stroke-cycle engine is installed the exhaust-gas turbine might possibly be adopted for driving a supercharging pump, so that the engine, instead of having the air in the cylinders at atmospheric pressures at the beginning of the stroke, would have it at a pressure a few pounds per square inch above this. (Editorial in *Shipbuilding and Shipping Record*, vol. 26, no. 21, Nov. 19, 1925, pp. 517–518, *g*)

Checking Boiler Performance by the Use of Steam Traps

DATA of tests made by John Williams, chief engineer of the Chase Metal Works, and by a large steel company in the East. The first of the tests were made to determine which pair of a battery of four boilers was throwing more water over into the superheaters. To determine this, on each leg of the steam pipe running from the saturated steam drums to the superheaters an Armstrong trap was installed, the connection being made with 3 ft. of $^3/_4$-in. pipe, and proper temperature recorders were installed. It was found that the pair of boilers which was supposed to be throwing over the most water were throwing off the least; incidentally it was found that the trap draining the line on the boilers throwing the most water discharged 12 times per hour. The value of insulation was also demonstrated during this test. The first tests were made with the line to the traps and the traps themselves uninsulated. Under these conditions one trap discharged 15 times per hour and the other 20 times. Then both the connecting pipes and the traps were heavily insulated; thereafter one trap discharged 9 times per hour and the other 12 times. The area of the surface of the pipe and trap amounted to approximately 1.895 sq. ft.

In the case of the first trap, which discharged 15 times per hour with pipe and trap uninsulated and nine times per hour with the trap and pipe insulated, there was a difference of six discharges per hour, which at 0.4 lb. per discharge, equals 2.4 lb. per hr. The difference in the amount discharged by the trap in the outer case was somewhat greater, the trap discharging 20 times per hour before insulation or a difference of eight discharges per hour, amounting to 3.2 lb. per hr.

A comparison of the square feet of radiation and the amount of steam condensed by this radiation is of interest. While these figures are not at all conclusive, yet the reader will note that in case of the first trap the difference in the amount of condensation, or 2.4 lb. per hr., was directly due to the heat loss from the pipe and trap before being covered, and as the surface was 1.895 sq. ft., this means over 1 lb. of condensate per sq. ft. per hr., 1.266 lb. to be exact.

Now ordinarily steam traps are rated on the basis of the rule of heating engineers to allow from 0.25 to 0.33 lb. condensate per square foot of radiation. In view of the results of the tests described, which, by the way, were not made with the idea of determining the amount of condensate per square foot, it is evident that rating traps according to the practice of heating engineers is not correct, and the purchaser of steam traps should take this into consideration not only when selecting traps for their requirements but when

comparing prices. It is obvious that a comparison of the price of two high-grade steam traps will not be fair if they are compared on the basis of their rated capacities in square feet of radiation when one trap is rated on the basis of $^1/_4$ lb. of condensate per hour from the radiation while the other trap is rated on the basis of $1^1/_4$ lb. (L. D. Goff, Sales Mgr., Armstrong Machine Works, in *Steam Power*, vol. 4, no. 10, Nov., 1925, pp. 5 and 8, 1 fig., *ep*)

An Air Heater

DESCRIPTION of the Blaw-Knox regenerative air heater. The apparatus has three compartments in which the heating elements are placed. Each of these compartments has two mushroom valves in top and bottom which are hooked up in pairs as shown in Fig. 5. Below and above these chambers are other compartments of flues which extend over all three chambers as shown. Hot waste gases enter the lower right flue and flow through the chambers where the right-hand pair of valves are opened into the fulcrumed at the left and the right side, and the valve-lifting rods are lifted by the ends of this rocker. The result of this motion is that the valves are alternately lifted during a certain interval of time, held stationary for another period, and lowered during the third period. The exact motion of the valves depends on the shape of the cam, and the mechanism acts in such a way that one of pair valves are completely closed before the other pair opens, so that there is no short-circuiting of air to the waste gases. The valves are also so hooked up to the lifting rods that they seat themselves by their own weight regardless of the relative expansion of the rods and the casing.

Each pair of valves opens continuously during 60 deg. turn of the camshaft, stay open during another 60 deg., close during the next 60 deg., and remain closed during 180 deg. A diagram of the valve motion is given in the original article. There is a continuous flow of both air and waste gases through the heater, and the valve motion is so slow that no shocks can occur due to either valve

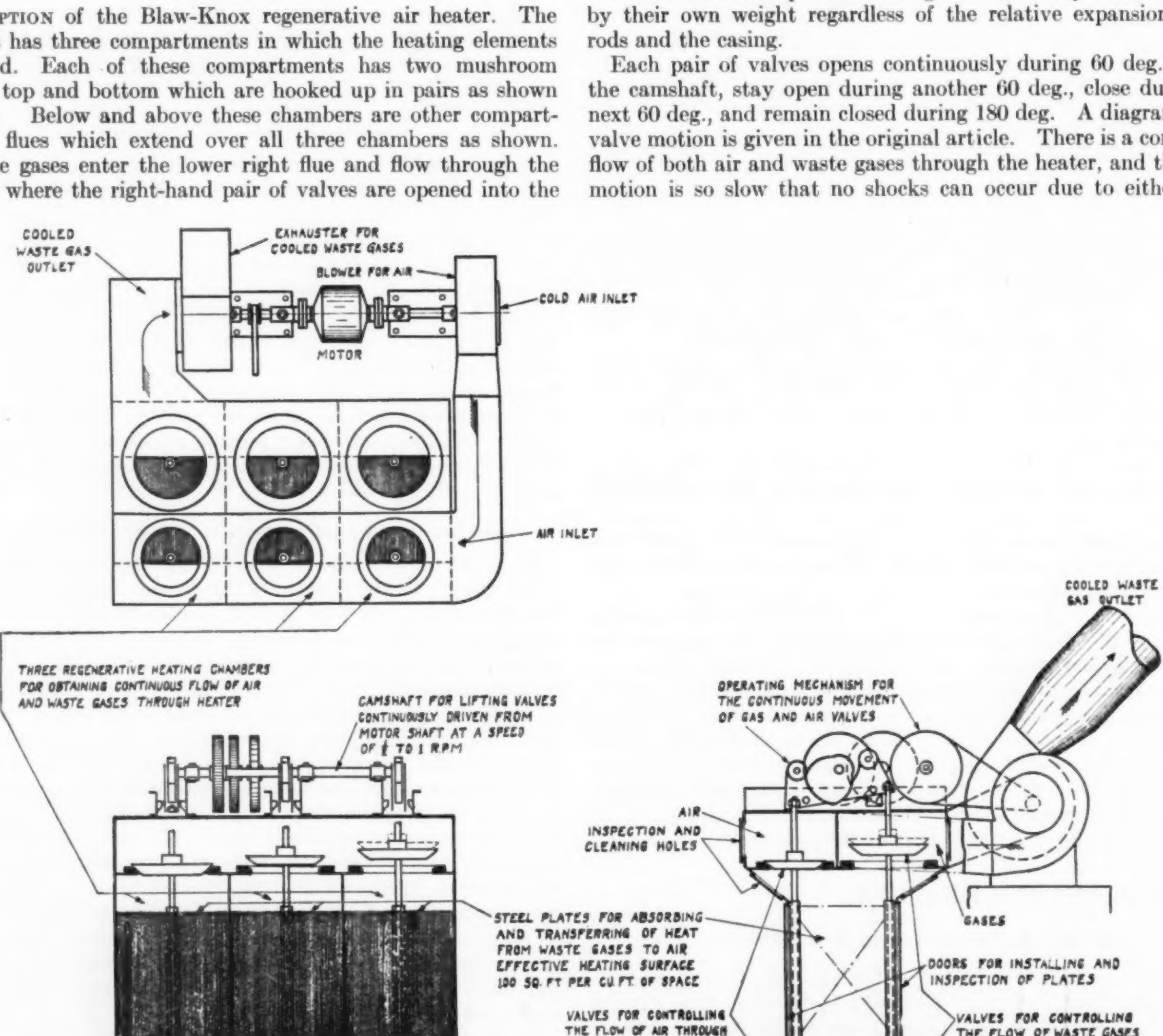

FIG. 5 BLAW-KNOX REGENERATIVE AIR HEATER

upper right flue, and from there to an exhauster. In passing through the chambers the heat is taken up by the heating elements which consist of a large number of thin steel plates. The air is blown into the upper left flue and enters the chambers. The left pair of valves are opened, extracting heat from the steel plates before entering the lower left flue, from which the hot air flows to the combustion chamber.

The way the valves are arranged and the way they are operated in connection with the three chambers are claimed to be novel. The valves are continuously operated by a mechanism placed on top of the heater. (Fig. 5.) This mechanism consists of a shaft which is continuously driven at a very low speed. This shaft has three cams which are placed at an angle of 120 deg. from each other. Each cam works against rollers on a rocker, which alternately is opening or closing. The loss of air due to the free volume in the regenerative chambers is said to be from 1 to 2 per cent, and is therefore practically negligible. It is also possible to produce exactly pure heated air at a slightly increased loss of air by having the gas outlet valve close a fraction of a second after the opening of the air inlet valve, so that the chamber is purged from waste gases before heated air is produced.

The three-chamber heater is made in several sizes, the largest being capable of handling about 170,000 lb. of waste gases per hour. The author compares the heater he describes with the apparatus now used in steel works for producing hot blast for blast furnaces.

In the discussion the following remarks were made by Geo. A.

Orrok, Mem. A.S.M.E. "Preheaters are very old. They go back a hundred years; they have been used practically continuously for a hundred years. The Howdens system and the Ellis-Eaves system have been used sixty years on ships, and, to some extent, on land—and very satisfactorily. It is only during the last three or four years we have been hearing about air heaters in order to save the last few per cent we thought was going up the stack. Air heaters can only save that percentage that goes up the stack plus a very little more, of small moment, in combustion; how much more nobody knows at the present time. We do know that a boiler operating at 45 per cent efficiency can add about 50 per cent to its efficiency, bringing it up to 67 per cent if it puts the Howden system on. A boiler running at 88 per cent efficiency can probably add one-half of one per cent to its efficiency by the use of an air heater; and that no matter how much surface you use—because your flue gases only contain about four per cent of the total heat in the coal. The amount you can save from that is comparatively small. There must be some sensible heat in the gases going up the chimney; and your moisture loss will always go up the chimney—the heat from hydrogen and the moisture of the coal. But if you run below the dewpoint in your gases, your heater goes to pieces in a short time.

"As to the method of calculating air heaters, it depends on whether you take an ordinary tubular boiler and put an air heater on it, or one with economizers.

"Back in 1881 Mr. Hoadley tested a return tubular boiler in the Pacific mills with an air heater. Without the air heater he got 81 and a fraction per cent efficiency; with the air heater he got 82 and a fraction per cent. The air heater was a tubular heater and very carefully made; and his return tubular boiler had a setting that was very good indeed, and Mr. Hoadley did most of the firing himself—which was responsible for the very good efficiency obtained. He was one of the best engineers the country has produced.

"I was reading the other night about some tests that were made on a marine installation in about 1860, where, as I say, the boiler efficiency was increased about 50 per cent—from about 40 per cent to 60 per cent. I think you have between those two percentages to work on with your air heater.

"There is one other point. Remember that of your total heat used in the cycle you waste out of the condenser on a general average around 55 per cent, while the heat that goes up the stack is anywhere from four to sixteen per cent, or even higher." (Part of a discussion on the subject of Extending the Heat Cycle in Boiler Rooms by the Use of Preheated Air for Combustion Purposes, before the annual convention of the Association of Iron and Steel Electrical Engineers. Description of the Blaw-Knox heater taken from discussion by Waldemar Dyrsson, chief engineer, Hammer Weld and Furnace Equipment Departments, Blaw-Knox Co., Pittsburgh, Pa. *Iron and Steel Engineer*, vol. 2, no. 11, Nov., 1925, pp. 464–468, 6 figs.; discussion by Geo. A. Orrok, p. 468, *dp*)

New Central Station at Rummelsburg, near Berlin

DESCRIPTION of a new municipal electric power plant, said to be the largest to have been built in Germany since the war. It will contain three steam turbines each of 70,000 kw. capacity, operating in three stages and driving two independent shafts. The high-pressure and intermediate stages drive one shaft and the low-pressure the other, both running at 1500 r.p.m. and each driving a 35,000-kw. generator feeding into a 44,000-kva. step-up transformer (from 6000 to 30,000 volts). The initial steam pressure is 485 lb. at 750 deg. fahr.

An interesting feature of the plant is the use of superheat turbines. There are three such units of 10,000 kw. capacity each, one for each main-turbine unit; they are placed between the two boiler houses under the same roof as the feedwater pumps, etc. These superheat turbines serve a double purpose; in the first place, exhaust steam is bled from them to preheat the feedwater and supply heat to the driers; in the second place, they produce electric power for the auxiliaries which are thus made more accessible.

The boilers (sixteen, each of 19,150 sq. ft. heating surface) are arranged in two boiler houses, each being a self-contained unit consisting of boiler, economizer, and air preheater. The boilers are fired by pulverized coal. The deciding factor in determining upon the use of this system was the desire to be independent of any particular type of fuel. The pulverizing is done on the premises. The kiln driers use exhaust steam from the superheat turbines.

The original article contains an interesting comparison between the Rummelsburg plant and the Golpa plant at Bitterfeld, built in 1915, and considered until very recently the last word in power-plant engineering in Germany. Three 70,000-kw. turbines with 16 boilers are employed for a total output of 210,000 kw. at Rummelsburg; the Golpa plant with an output of 128,000 kw. uses eight turbines and 64 boilers. The result is that the new plant requires one-third less calories per useful kilowatt-hour than the Golpa installation. The saving in labor is said to be even greater. (Dr. W. Kajerczik in *Die Wärme*, June 26, 1925, translated in *Combustion*, vol. 13, no. 6, Dec., 1925, pp. 355–356, 1 fig., *d*)

RAILROAD ENGINEERING (See also Power-Plant Engineering: Pitting and Corrosion in Boiler Flues)

A Double-Drive Motor Rail Car

THE Susquehanna and New York Railroad, operating between Williamsport and Towanda, Pa., a distance of forty miles, is receiving a new type of gasoline motor car. The novel feature of the car, which is of all-steel construction, is that it is equipped with two 75-hp. gasoline motors driving both the front and rear trucks. Both motors are at the front end of the car and are independently connected to a common gear box by means of a clutch so that either engine or both are available for use at the will of the operator. A single lever performs all of the functions of starting, stopping, or clutching in the engines, and the operation of this lever is such that it is impossible to perform the different functions in wrong sequence. Each motor is fitted with a special form of synchronizer, so arranged as to prevent racing when the second engine is started or stopped by the use of the clutch. Usually if a rigid power drive is made to more than one axle a power loss is experienced (amounting to 15 per cent of the power necessary to propel the car), especially on a good rail, due to the uneven rolling of the wheels of the two driving axles. In this case it is claimed that this loss was eliminated by a special arrangement not described in all details. (W. W. Baxter, Editor Mechanical Department, in *Railway Review*, vol. 77, no. 22, Nov. 28, 1925, pp. 807–809, 2 figs., *d*)

Steam-Turbine Locomotives

AN ATTEMPT to consider the problems involved in the design of an efficient steam-turbine locomotive. The author devotes his chief attention to the consideration of the turbine-locomotive auxiliaries and comes to the following conclusions: The energy consumption of the air pump on a 100 per cent efficiency basis is 93.2 ft-lb. per lb. of steam; the energy consumption of the condensate and feed pump is 495 ft-lb. per lb. of steam; the consumption of the water pump is 1880 ft-lb. per lb. of steam, while the consumption of the air cooler is 1730 ft-lb. per lb. of steam. For the blast fan the consumption is 3800 ft-lb. per lb. of steam. All of the above is on the assumption of 100 per cent efficiency. Assuming the following efficiencies, air pump 70 per cent, feed pump 60, first cooling pump 60, second air cooling 50, and blast fan 60 per cent, the author gets 0.0165 hp. per kg. of steam per hour. Assuming for a 4-cylinder compound the total consumption of steam to be 4.47 kg. per hp-hr. while the consumption of the auxiliaries is 7 kg. per hp-hr., the total consumption may be $4.47 + (0.165) \times 7 = 5.12$ kg. Against this we have a saturated simple engine with a consumption of 11.4 kg. per hr., a 2-cylinder compound of 10.0 kg. per hr., and a simple superheater of 7.2 kg. per hr.

The various transmissions and the influence of the transmission gear upon design are discussed next. As regards the location of the turbine, the author recommends placing it across the frames and driving to a blind axle. With this arrangement a more efficient distribution of the weight is secured, also steam pipes are kept short; and exhaust pipes at less than atmospheric pressures are rigid and of ample capacity, while the only piping to the tender is that for the steam to and from the fan turbines, and for water to and from the condenser on the boiler vehicle to the evaporative condenser or cooler on the tender. He considers the boiler-vehicle

condenser preferable, although it does not lend itself well to direct air-cooled condenser arrangement and almost commits to an evaporative condenser or at least a two-circuit system, i.e., a water-cooled surface condenser dealing with the condensate and a cooler to deal with the circulating water. The original article contains an interesting drawing of the geared-turbine-locomotive pipe system. (*The Railway Engineer*, vol. 46, no. 551, December, 1925, pp. 435–439, 1 fig., *dg*)

Texas-Type Locomotives

DESCRIPTION of a 2-10-4 type of locomotive delivered by the Lima Locomotive Works to the Texas and Pacific Railroad. The interesting features of this type include four-wheel booster-equipped articulated trailing trucks, and produce immensely powerful engines which it is expected will be capable of handling at least 3000 gross tons over grades which are approximately 1.25 per cent in much less time than is required by other engines now in service in that territory.

While the cylinders of these engines resemble in general appearance that of the usual set of cylinders commonly applied to locomotives at present, they are distinctly different in many ways. The most outstanding feature is that they are constructed entirely of cast steel, and all cored passages are eliminated, thus making it possible to produce cylinders of ample strength that are light in weight and have thin walls. Another interesting feature incorporated in the construction is the arrangement of the front and back valve-chamber heads and the exhaust-steam passages. Two flanged connections are provided on each of the two front valve-chamber extensions, one for the exhaust pipes from the cylinders to the exhaust nozzle, and one for the pipes used for conveying the exhaust steam from the cylinders to the feedwater heater. On the back valve-chamber extensions or heads, which also carry the valve crosshead guides, there are flanged connections for the back exhaust-steam pipes. From further reference to the accompanying illustration, it may be noticed that the exhaust passages are not cast integrally with the cylinders as is the usual practice, but instead, four exhaust pipes, entirely separate from the cylinder castings, have been provided. One end of each exhaust pipe is bolted directly to the end of the valve-chamber extension and the other to the end of the cylinder casting under the saddle where they connect with short, straight passages in the cylinders leading directly to the exhaust nozzle. The saddle-joint faces, frame pads, steam-pipe and relief-valve connections, and the general arrangement are almost identical with the usual type of cylinders made of cast iron.

By constructing the cylinders of these engines of cast steel instead of cast iron their weight was reduced materially, all of which was utilized to much better advantage in increasing the size and capacity of the boiler. Furthermore the construction is such that practically every portion of the cylinders is easily accessible for inspection or repairs. Another decided advantage in this form of construction is that the areas of the exhaust passages may be made almost any desired size, as they are in no way restricted as usually is the case when they are cast integrally with the cylinders. Still another advantage to be had from this form of construction, and cast steel as a material, is that repairs may be made easily; such as welding cracks or repairing any defects which might develop in operation, inasmuch as almost all of the surfaces of the cylinders are accessible.

The cylinders of these Texas-type engines are 29 in. in diameter and have a stroke of 32 in. with 14-in. piston-valve chambers. The cylinders and the valve chambers are bushed with Hunt-Spiller gun iron, as is now becoming common practice, and the front cylinder-head studs are provided with breakage grooves. Okadee drain valves are used in the exhaust-steam passages, and the cylinder cocks employed are of the Hancock type, pneumatically operated.

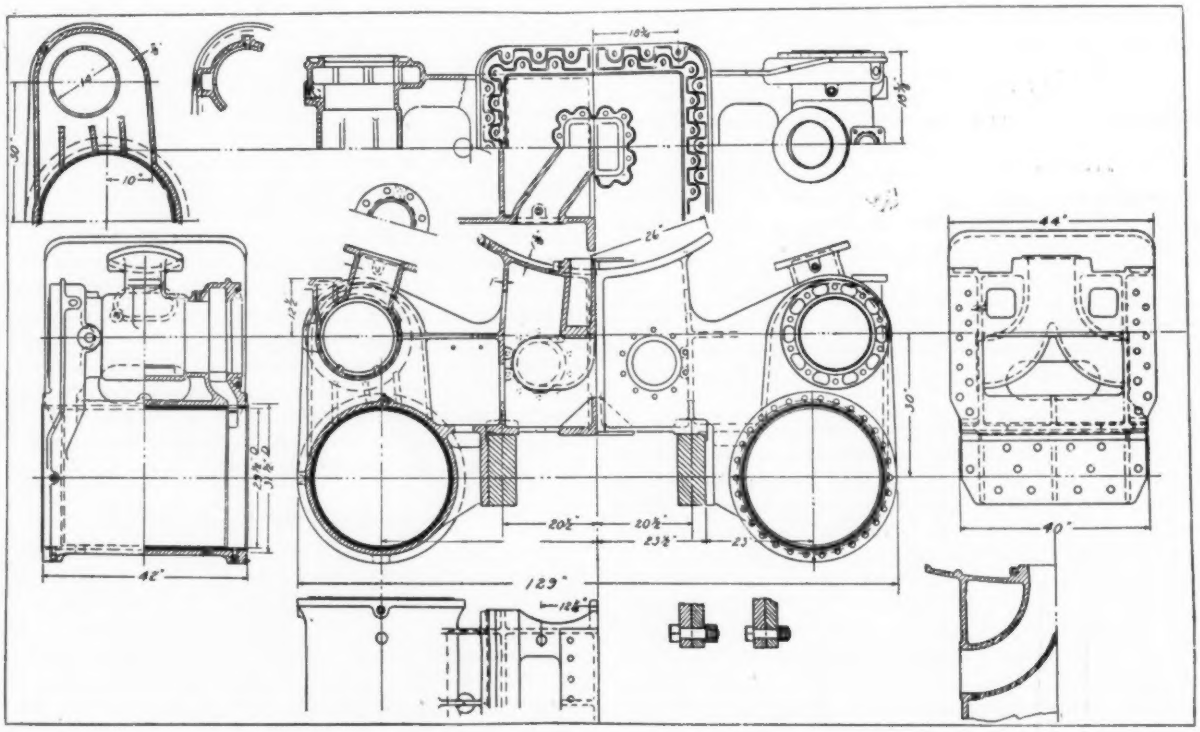

FIG. 6 DETAILS OF CAST-STEEL CYLINDERS USED ON TEXAS & PACIFIC 2-10-4 TYPE LOCOMOTIVES

The limited cut-off with compensating ports has been applied to these new engines for two reasons. First, their arrangement at low speeds produces a very uniform turning moment with the result that a much higher average tractive power for a given driver-wheel weight can be obtained than with a full-stroke locomotive. With 250 lb. boiler pressure and the 60 per cent cut-off, it is estimated that the tractive power of these engines is about 83,000 lb. The ratio of this tractive effort to the weight on the drivers is 3.61, which is an unusually low factor of adhesion for engines of this size. The engines, however, are not slippery, because of the even turning moment. The trailing-truck booster has a tractive force of 13,000 lb., which combined with that of the engine makes the initial starting effort of these locomotives 96,000 lb. A peculiar cut-off is used, lengthened at the forward end of the cylinder at slow speeds only, thus improving the turning moment. (W. W. Baxter, Editor Mechanical Department, in *Railway Review*, vol. 77, no. 25, Dec. 19, 1925, pp. 905–912, illustrated, *dA*)

REFRIGERATING ENGINEERING (See also Thermodynamics: Ratio of Specific Heats and Joule-Thomson Coefficient for Ammonia)

Von Platen and Munters Refrigerating Apparatus

FURTHER data on the device described in MECHANICAL ENGINEERING, vol. 47, no. 7, July, 1925, p. 588. In this device there are no moving parts, and by application of heat to a coil in one portion of the apparatus, refrigeration is obtained in another portion, the pressure being the same in all parts of the apparatus. (The Production of Low Temperatures, *Teknisk Tidskrift*, Stockholm, Sweden. Translated in *Refrigerating Engineering*, vol. 12, no. 5, Nov., 1925, pp. 147–148, *d*)

SHIPBUILDING

A Novel Triple-Screw Arrangement

TRIPLE-SCREW vessels are not very numerous, and the arrangement has been principally adopted in ships which have been fitted with the combination type of machinery. Screws of large diameter, driven by reciprocating engines, are fitted in the wing positions, and turbine machinery, supplied with the exhaust steam from the reciprocating engines, drives the center propeller. It has been a matter of some difficulty to obtain reasonably good propulsive results with this system, and if a good performance is to be realized a proper distribution of power and careful selection of propellers must be accomplished. Dr. Gebers, of the Vienna experimental tank, has been investigating the possibilities of a triple arrangement in which the wing screws will be of the vane type, as invented by Wm. Denny & Bros., and the center screw will be very deeply immersed. It has been clearly demonstrated by the actual trials of light-draft vessels that these vane propellers secure an abnormally high degree of efficiency, the boss and shaft resistance having been eliminated owing to these being above the surface of the water. Equally good results can be reasonably expected from the wing propellers in the Gebers' arrangement, but whether a small, fine-pitched, high-speed central screw can be relied upon to be of efficient service in actual propulsion, is a debatable point. It is said that for cruising purposes the center screw only would be operating, which would suggest that the arrangement would be particularly suitable for war vessels. (*Shipbuilding and Shipping Record*, vol. 26, no. 21, Nov. 19, 1925, pp. 507, *e*)

SPECIAL APPARATUS (See Thermodynamics: Heat Flow in Pyrex Condenser Tubes)

STEAM ENGINEERING

Steam-Nozzle Research

Now that the first main program of tests has been completed, the Committee feel that a general review of their work would be appropriate at this stage.

Convergent Impulse Nozzles. The proportions of the impulse nozzles were chosen as representing extreme cases met with in modern practice. Very thin and very thick partition plates were used, and very large and very small angles. No attempt was made to improve the rough finish of the steam passages, but the nozzles were successively cut down from a very long throat to no throat at all. A wider range of steam velocities was found possible than with any previous published tests, and curves were consistently obtained which showed the deviation of the velocity coefficient for theoretical steam velocities between 300 and 2000 ft. per sec. The accuracy of these curves was of the order of ± 1.0 per cent at very low velocities, ± 1/2 per cent at medium velocities, and ± 3/8 per cent at the higher velocities. Care was taken throughout to maintain comparative conditions. The only deviations were the degree of initial superheat, and, in the case of the 12-deg. thick-plate nozzles, a setting of 4 in. away from the top mesh of the cage plate instead of 2 1/2 in. as in all the other tests; but experiments are shown which prove that this distance effect does not affect the comparison. A method of correction for superheat is applied to all the curves of the research, and the mean lines shown in Fig. 7 are obtained for the two extreme cases when the throat is three times the length of the opening and when there is no throat at all. In order to summarize the results still more Fig. 8 has been added. This shows the effect of cutting down the throat from between 3/1 and 0/1 at a theoretical velocity of 1200 ft. per sec., and includes intermediate points for 3/1 and 1/1 throats not shown in Fig. 7.

Effect of Throat Length. It appears that this depends to a considerable extent on the nominal angle of the nozzle. Whereas a 20-deg. angle shows practically no difference between 2/1 and 0/1 for either thin plates, thick plates, or chamfered plates, a smaller-angled nozzle of 12 deg. shows successive improvement in all cases between 3/1 and 1/1.

Effect of Thickness of Partition Plates and of Chamfering. In all

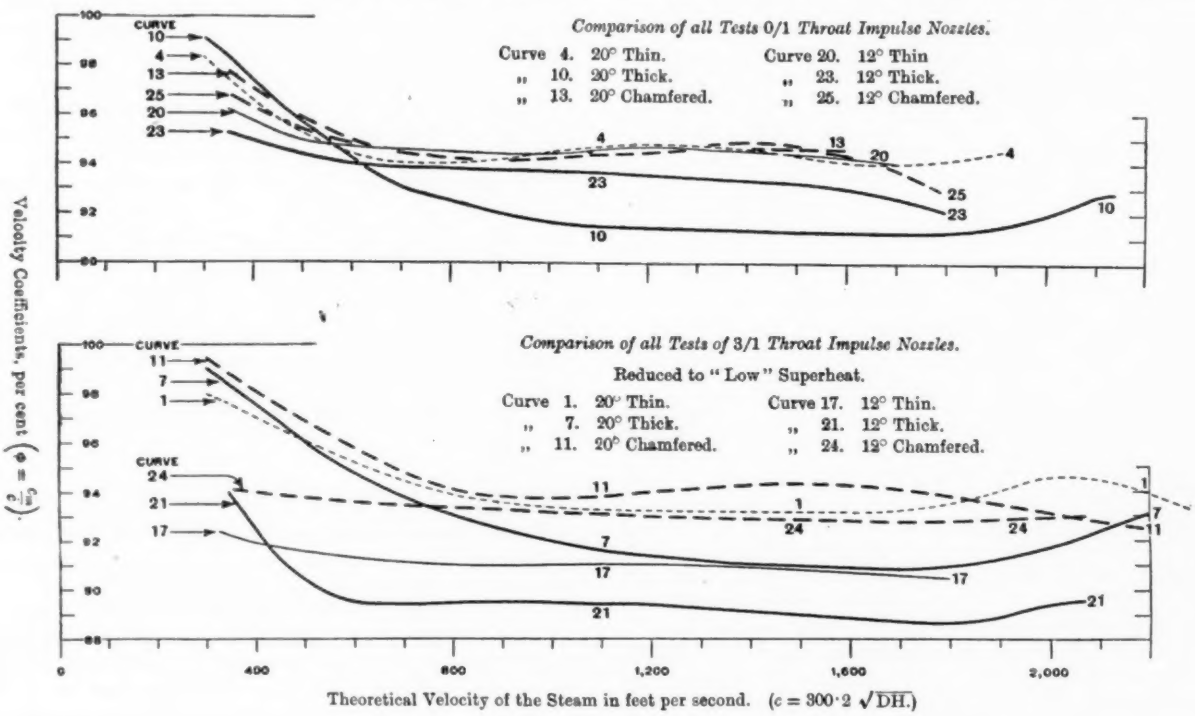

FIG. 7

cases, for any given angle, *unchamfered* thick partition plates gave worse results than thin plates. If, however, a suitable chamfer is worked on the back of each partition plate, so as to eliminate the flat surface in the exit plane of the nozzle, then neither the length of the throat nor the angle of the nozzle makes any appreciable difference over the usual working range of impulse nozzles. Moreover, in all cases the result of chamfering the thick partition plates lifts the value of the velocity coefficient (and therefore of the efficiency) up to or above the corresponding values for thin plates. In other words, a chamfered thick partition plate gives quite as good results as a thin plate, irrespective of the angle of the nozzle.

Effect of Angle of the Nozzle on Efficiency. The angle effect is to some extent interconnected with the length of parallel throat.

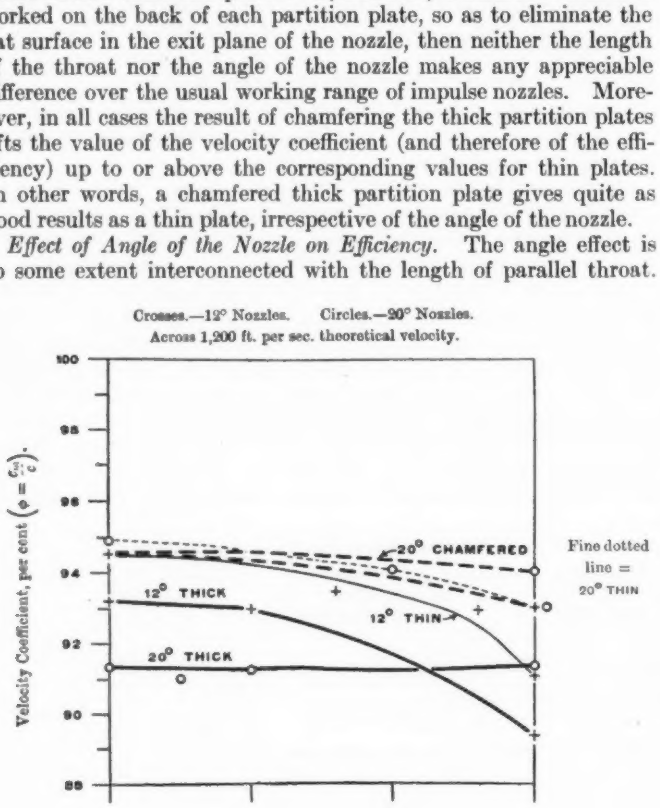

Fig. 8

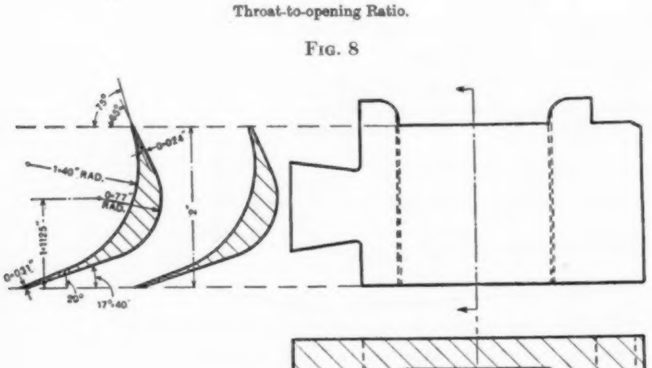

Fig. 9 Impulse Nozzle Used on a 5000-kw. Turbine Supplied to the L.C.C. Power Station at Greenwich in 1910

The longer the throat the more definitely worse are the 12-deg.-angle nozzles when compared with their corresponding 20-deg. nozzles. There appears to be one exception to this, the thick-plate unchamfered nozzles. The throat effect here predominates to such an extent that whereas the 20-deg. nozzle does not alter as the throat is cut down, the 12-deg. nozzle shows a steady improvement. The consequence is that below a 2/1 throat a better result is obtained with the smaller angle. This anomaly is not of serious practical importance, since both nozzles showed themselves to be, in general, worse with the unchamfered thick plates than under any other conditions of test.

There is, however, another effect of angle which should be noted. All the 20-deg.-angle nozzles (as well as the reaction nozzles) showed a more or less pronounced rise below a velocity of about 700 ft. per sec. as this velocity was further decreased to 300 ft. per sec. This effect was present to a very much less degree in the case of the 12-deg.-angle nozzles. The curves, in general, were nearly flat throughout their tested length. Here, again, there appears to be one exception, the 12-deg. angle unchamfered thick-plate nozzle with a 3/1 throat. But even in this case the upward bend is considerably modified with the shorter throats.

General Efficiency Considerations. All these effects may be summed up in the following statement. There is a wide variation permissible in the design of converging impulse nozzles when *maximum efficiency* is the chief consideration. Thick partition plates can give as good an efficiency as thin plates, provided they are carefully chamfered to exit. Below a 2/1 throat-to-opening ratio the length of throat has little effect, provided the angle of the nozzle is 20 deg., but throats longer than 1/1 should be avoided with smaller angles. Between 1/1 and 0/1 the angle of the nozzle may vary between 20 deg. and 12 deg. without appreciable loss in efficiency. Conditions both of entry and of exit are important. The steam should enter the nozzle passage with the minimum amount of shock, and flat surfaces in the exit plane of the nozzle should be avoided.

Efflux Angles of the Steam. The efflux angle of the steam from a nozzle is very simply measured by the apparatus devised by the Committee and described in their Third Report. In general it was found (below the critical pressure ratio) to be more nearly equal to the angle whose sine was o/p (where o is the throat opening and p the pitch of the nozzle) than to the nominal angle of the nozzle whose sine was o/q. It was found, in general, that shortening the throat tended to flatten any deviations there might have been over different pressure ratios down to the critical value, and this can only legitimately be applied to the shape of nozzle tested by the Committee. The built-in type of impulse nozzle, for instance, showed considerable variation in angle with practically no throat. The Committee suggest that most useful information can be obtained on this point without difficulty or great expense, if a sample nozzle box of any particular type is made up and tested for efflux, as the efflux angle is of such importance in the design of impulse turbines.

The work of the Committee is still continuing. Preparations are being made to test nozzles over a different pressure range, up to 60 lb. per sq. in. gage on the exhausting side. It is also proposed to test some elementary straight nozzles of rectangular and square section. (*Proceedings of the Institution of Mechanical Engineers*, no. 4, 1925, pp. 747–843; this abstract taken from pp. 773–778, *eA*)

TESTING AND MEASUREMENTS (See also Power-Plant Engineering: Checking Boiler Performance by Use of Steam Traps)

Tests of Airplane and Other Fabrics

Abstract of the first report of the Fabrics Coördinating Research Committee of the Department of Scientific and Industrial Research (Great Britain). The Committee was set up in 1921 to serve as a clearing house for the information accumulated in the various government researches. The report covers the period up to July, 1924, and is devoted largely to investigations of general problems in which the nature of the textile fiber was not the main factor.

The conditions of use, especially those of climate, seem to determine the relative importance of the causes that lead to the deterioration of fabrics. Thus, airplane and airship fabrics suffer from light; tents, especially in hot, damp climates, from microorganisms; and in every class of deterioration chemical action is thought likely to be present to some extent, and in some instances, such as fireproofing, to be the predominant factor. On tents alone the cost of replacement based on prewar requirements and prices in 1922 was about £200,000, and the average life of a tent, even in England, is said to be only twelve months.

Accordingly, measures were taken at an early date for investigating the nature and extent of the deterioration caused by light and by microörganisms, including with the latter group of inquiries an investigation into the deterioration of fishing nets, which forms a substantial item of expense to the fishing industry. Except in the investigations in regard to fireproofing the Committee has made no definite inquiry into deterioration by purely chemical action, knowing that investigations of the kind are being carried out by the industrial research associations.

In practically all lines of investigation it is necessary to determine the tensile strength of the fabric, a matter on which there appears to be still a good deal of doubt. Existing specifications, including those of the British Engineering Standards Association, have standardized the method of preparing test specimens, but numerous other factors such as the adjustment of an even initial tension in the test piece, the humidity of the atmosphere, the rate of loading, and even the capacity of the machine, have been found to affect the results.

The size of specimens suitable for light fabrics such as are used in airplanes has been investigated at the National Physical Laboratory, and specimen 6 in. long and 2 in. wide has been adopted as a standard for such materials. The standard size for heavy fabrics is now under investigation.

On the other hand, the effect of humidity is more difficult to control. During the war fabrics were tested, but no constant relation could be traced between the wet strength and that under ordinary conditions of dryness. The British Engineering Standards Association therefore reverted some four years ago to the dry test, and specified that it should be made in air of 66 per cent humidity. This, however, was easier to specify than to procure. Few laboratories have facilities for controlling humidity, and even these are said to be at present imperfect. One sub-committee of the British Engineering Standards Association is said, in fact, to have again reverted to the wet test. Some American work has shown that on heavy fabrics the discrepancy is even more serious. For the time being, therefore, the testing of fabrics of which the hygrometric state may vary, as it must in practically all untreated fabrics of textile materials, remains an unsolved problem. Variations up to 25 per cent or more are said to occur between the results of tests under different conditions of moisture, and the only practicable course seems to be to ascertain, if possible, the most exacting hygrometric conditions to which the fabric will be subjected in use, and to test under those conditions, leaving the presence of more favorable conditions as an addition to the factor of safety.

But even excluding the element of humidity, or supposing it constant, the method of loading the testing machine offers considerable practical difficulty. Machines may be constructed either to maintain a constant load on the fabric, or to pull it apart at a constant rate. The choice between these systems, as well as the rate at which the load is applied, has a considerable effect on the test result. It is indeed thought that before really accurate tests can be made on textile materials, some form of machine will have to be devised in which the elasticity of the material exerts no influence on the rate at which the load is applied. An American machine has, in fact, been described which is said to satisfy this condition, but no results from it are given in the report.

Several investigations have been made into the effect of the same machine rate of load—that is, the load indicated per inch of travel of the moving jaw which would correspond to the true rate of load on the fabric if the fabric were inextensible—when applied on machines with different capacities. The effect of these is to show that the size may be a very material factor, and the same fabric, tested on machines of different capacities, may give as much as 10 per cent difference in breaking strain. A series of tests was made at the Manchester Chamber of Commerce Testing House and Laboratory as between three testing machines in common use, which showed that there was no constant relation between the strengths recorded by two of the chief machines for different fabrics, even when the fabrics were of similar total extension. In another series of tests it appeared that in both machines a wide variation existed between the results of individual tests, which in this series were made on 500 specimens of the same material. With one machine the individual specimens varied in breaking strain from 370 lb. to 485 lb. on one machine, and from 410 to 495 on the other. In a second series, made on 1000 pieces, the results were somewhat similar. It seems, therefore, that the intrinsic variation in strength in the same material is considerably in excess of any likely difference between the results given by different machines. It may be possible to improve the uniformity of strength in the material. In the meantime no doubt can be felt that such modifications in design of the machines as will enable results from them to be more strictly comparable are worth making. In the opinion of the Committee, it seems at present to be impossible to standardize methods of testing fabrics completely, and for the time being its attention is devoted to accumulating accurate information and endeavoring to solve minor problems bearing on the more general question. Certainly this policy seems preferable to that of setting up standards on inconclusive data which later experience may discredit. (*Engineering*, vol. 120, no. 2305, Nov. 20, 1925, pp. 638–639, *ep*)

THERMODYNAMICS

Heat Flow in Pyrex Condenser Tubes

The data regarding heat flow in such tubes are given in the form of curves. It would appear that the surface-film resistance is practically the controlling factor in the case of metal condenser tubes, and that volume conductivity has only a small effect. Copper has about six times the conductivity of steel, yet it condenses only about ten per cent more steam than the steel. This difference is perhaps due to the surface smoothness of the copper and the absence of scale, for when the copper was oxidized the condensation value dropped below that of the steel. Copper having a conductivity coefficient of more than three hundred times that of Pyrex glass only condenses 2.5 times as much steam for the more rapid rates of flow. (Report of the winter meeting of the American Institute of Chemical Engineers, December 2 to 5, 1925, in Cincinnati. Abstracted through *Chemical and Metallurgical Engineering*, vol. 32, no. 18, Dec., 1925, pp. 933–934. The paper here abstracted pp. 932–933, 1 fig., *e*)

VARIA

Migration of the American Aluminum Industry to Canada

It is stated that the whole of the aluminum industry of the United States, involving a capital of hundreds of millions of dollars, is to be moved into Quebec Province as a result of power developments on the Saguenay River. For many months the Aluminum Company of America is said to have been weighing the comparative water-power advantages offered by Canada and Norway, and it is understood that the cheapness and abundance of power swung the decision in the favor of Canada. The construction of the company's plant, including the power development, will mean an investment of over $100,000,000. The industry secures its raw product (bauxite) from British Guiana, and the transport of this will mean the establishment of a company line of at least fifteen steamships between the Saguenay and the Guiana coast during the navigation period.

The power requirements are estimated at something in the neighborhood of 750,000 hp. and the establishment of the new industry will mean the creation of a city of 50,000 people on the Saguenay River. Preliminary engineering work in connection with the site is already going ahead at the Saguenay location. It is proposed to employ direct rather than alternating current at the plant, which will call for more than ordinarily costly machinery. (Article in the Toronto *Globe*, abstracted through *Iron and Steel of Canada*, vol. 8, no. 11, Nov., 1925, pp. 245–246, *g*)

Divining Rods and Dowsers

At the request of the Society for Physical Research an investigation of the whole problem was carried out by Prof. W. F. Barret, holder of the chair of Experimental Physics in the Royal College of Science of Ireland. His conclusions as to the twitchings of the rod are that the movement of the rod is not due to trickery nor any conscious voluntary effort, but is a more or less violent automatic action that occurs under certain conditions in certain individuals. (Abstracted through *English Mechanics*, vol. 122, no. 3164, Nov. 13, 1925, p. 256, *g*)

CLASSIFICATION OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general; *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the Society.

Engineering and Industrial Standardization

Standard Definitions Relating to Heat Treatment

THE American Society for Steel Treating, the Society of Automotive Engineers, and the American Society for Testing Materials have organized a joint committee to study definitions of terms relating to heat treatment. The representatives of the three organizations are as follows:

American Society for Testing Materials

George B. Waterhouse, professor of metallurgy, Massachusetts Institute of Technology, Cambridge, Mass.

H. M. Boylston, professor of metallurgy, in charge of department of metallurgy and mining, Case School of Applied Science, Cleveland, Ohio

John H. Hall, metallurgical engineer, Taylor-Wharton Iron and Steel Co., High Bridge, N. J.

Society of Automotive Engineers

Hugh P. Tiemann, assistant metallurgical engineer, Carnegie Steel Co., Pittsburgh, Pa.

George L. Norris, chief metallurgical engineer, Vanadium Corporation of America, New York, N. Y.

Stanley P. Rockwell, President, Stanley P. Rockwell Co., 112 High Street, Hartford, Conn.

American Society for Steel Treating

Robert M. Bird, metallurgist, Bethlehem Steel Co., Bethlehem, Pa.

J. F. Harper

W. J. Merten.

The committee is already functioning and held one meeting in connection with the annual meeting of the A.S.S.T. in Cleveland last September, at which Mr. Harper was elected chairman of the Joint Committee and J. E. Donnellan of the A.S.S.T. staff was designated as secretary. At this meeting the committee discussed in detail the definitions submitted by the A.S.S.T. for such terms as annealing, quenching, carburizing case-hardening case, core, and cyaniding.

Four New Projects Proposed[1]

Pressure Gages. The American Engineering Standards Committee has recently received a request from a leading pressure-gage manufacturer looking toward the standardization of pressure gages, particularly with a view to cutting down the number of sizes which should be made. It appears that pressure gages in this country are now manufactured in the following fourteen sizes: 2, $2^1/_2$, 3, $3^1/_2$, 4, 5, $5^1/_2$, 6, $6^3/_4$, 7, 8, $8^1/_2$, 10 and 12 in. One maker believes, however, that 7 sizes, $2^1/_2$, $3^1/_2$, $4^1/_2$, 6, 8, 10 and 12 in., would fill all reasonable requirements. (This approximates to a geometric series, ratio 1.2 to 1.4.) It seems possible that a preferred-number series applied for this purpose by another maker might form a convenient basis for the selection of sizes, as, for example, $2^1/_2$, 3, 4, (5), 6, 8, 10, 12.

The manufacturer referred to points out that the burden of high cost brought about by the present multiplicity of sizes falls on the consumer, who, in his opinion, would be the principal beneficiary of any simplification and standardization that might be done. He expects to take up with other American gage manufacturers the possibilities of standardization work in this country. This might follow along lines that have already been quite extensively developed in Germany and Switzerland in connection with pressure and vacuum gages.

Pipe-Thread Taps. Suggestions have come to the A.E.S.C. through C. B. Auel, engineer, the Westinghouse Electric and Manufacturing Co., for standardization of pipe-thread taps, with particular reference to the squares and shanks.

Data furnished by Mr. Auel showed that the sizes of the squares on the $^1/_4$-, $^3/_8$-, $^1/_2$- and $^3/_4$-in. taps produced by five principal manufacturers varied from 26 to 34 per cent from one another. Suggestions or comments from readers who have had experience in the use of such taps, or have encountered difficulties on account of lack of standardization, will be appreciated. This project is nominally within the scope of the work of the Sectional Committee on Small Tools and Machine Tool Elements for which the National Machine Tool Builders' Association and The American Society of Mechanical Engineers are joint sponsors. Suggestions should therefore be forwarded to one or the other of these organizations.

Leather Belting. A prominent manufacturing concern of the Middle West has recently suggested that leather belting be standardized. In this connection it is interesting to note that a specification for leather belting has been prepared through the coöperative efforts of the Bureau of Standards and the Leather Belting Exchange. This specification was officially adopted by the Federal Specifications Board for the use of the departments and independent establishments of the Government, and is published as Bureau of Standards Circular 148. Unification of leather-belting specifications on a national basis may be desirable perhaps on the basis of the joint government and trade-association specification referred to above. General requirements of this specification cover quality of the leather, construction of the belting, chemical tests, physical tests, request for bids, packing, marking and shipping, and methods for chemical analysis.

The American Petroleum Institute some time ago organized a committee on the Standardization of Belting of which A. H. Riney, chief engineer of the Phillips Petroleum Co., Bartlesville, Okla., is national chairman. This Committee held a meeting in Los Angeles, Cal., on January 20, during the A.P.I. Meeting.

Milling Cutters. On March 25, 1925, the Division of Simplified Practice held a general conference to consider the program of size simplification of milling cutters which had been worked out by the manufacturers' committee. The conference approved the simplified list in the form proposed. During the discussion of the conference, however, the engineering societies through the procedure of the A.E.S.C. were asked to take up this project and further advance the standardization of milling cutters.

At the December, 1925, meeting of the Central Committee which is guiding the work of the Sectional Committee on the Standardization of Small Tools and Machine Tool Elements, this project was presented and discussed. The Committee approved it and suggested that preliminary publicity be given before the sub-committee is organized.

Those who are interested are asked to communicate with C. B. LePage, care of A.S.M.E.

Rating of Electrical Machinery

AT A MEETING of the Board of Directors of the Institute of Electrical Engineers held December 11, 1925, it was voted to submit the following four sections of the A.I.E.E. Standards to the Sectional Committee on Rating of Electrical Machinery for consideration:

Standards for Direct-Current Rotating Machines (No. 5)

Standards for Alternators, Synchronous Motors, and Synchronous Machines in General (No. 7)

Standards for Induction Motors and Induction Machines in General (No. 9)

Standards for Direct- and Alternating-Current Fractional-Horsepower Motors (No. 10)

Upon the approval by the Sectional Committee these four standards will be submitted to the sponsor and by it to the A.E.S.C. for approval as "American Standards."

[1] Part of the material for these notes was taken from a recent bulletin issued by the American Engineering Standards Committee to its sustaining members. This committee whose offices are at 29 West 39th Street, New York, N. Y., would be interested in receiving comments on the various phases of these new projects from the readers of MECHANICAL ENGINEERING.

Correspondence

CONTRIBUTIONS to the Correspondence Department of Mechanical Engineering are solicited. Contributions particularly welcomed are discussions of papers published in this journal, brief articles of current interest to mechanical engineers, or comments from members of The American Society of Mechanical Engineers on activities or policies of the Society in Research and Standardization.

Progress in Printing

To the Editor:

The report contributed by the Printing Machinery Division and published in the December issue of Mechanical Engineering, gives a comprehensive survey of the various methods of printing and of rotary web presses for executing them. The writer thinks it worthy of mention that letter-press printing has, within the last decade, seen much higher speeds achieved in printing on flat sheets—two new kinds of automatic presses printing at high speed direct from flat forms.

The report outlines the principal points in the development of printing machinery and equipment. Reference is made to *time* as being an essential element in successful printing. This fact is the inspiration for inventive genius to devise methods and equipment for speeding up all operations, and especially those operations between the setting of the type or copy and the printing operation itself. The time required for these preparations is to be reckoned as a characteristic of the corresponding printing process in the various methods of high-grade printing.

Time is of course a factor in all printing plants when viewed as manufacturing establishments, for such they really are. Every print shop has its production problems, its cost problems, and its management problems. All of these problems were formerly dealt with by the management without outside help or consultation. Recently, keen competition, sometimes ruinous competition, in the field of commercial printing has led to the use of improved accounting methods and standardized cost schedules. There is still room, however, for improvement in production methods in a large proportion of the plants in the various fields of printing.

Plant layout is quite as important to efficiency and economy in manufacturing a newspaper as it is in manufacturing the various goods of commerce. Many a publishing house has expanded with increasing business along lines of least resistance, until the routing of material or work in process has become complicated and wasteful. At the same time, mechanical equipment has become obsolete from the viewpoint of cost of maintenance or cost of operation, or both. Additional machine units are selected on a basis of perhaps undue emphasis on first cost, or perhaps without due investigation into the latest developments of the art. Mr. Charles F. Hart, mechanical superintendent of the New York *Times*, recently advised the American Newspaper Publishers' Association of the need for a bureau of standards or of research, and a report of his comments appeared in the *Editor and Publisher* of Nov. 14, 1925.

Standardization is another phase of progress which is benefiting various industries, but which is very slow of adoption in typography and in printing. The United Typothetae of America are working for the standardization of type forms. Manufacturers of newspaper presses now recognize only three standard sizes of sheet cuts or page lengths in American practice, as compared with a great variety a generation ago. Metropolitan newspaper publishers are still using pages of both seven or eight columns, and some have adopted nine columns as standard; while the width of column varies from 11 ems pica (1.833 in.) to 14 ems (2.333 in.). Some of these factors are in a state of flux, which may signify progress, but in some cases the absence of standards is traceable to inertia or a policy of laissez-faire. This means opportunity for sound engineering guidance.

The application of engineering principles to the printing industry can come only gradually and as the importance and value of such principles are recognized by those controlling or managing the industry. To win such recognition and appreciation for engineering principles and methods should therefore be one of the aims of the Printing Machinery Division of the A.S.M.E.

H. E. Vehslage.[1]

New York, N. Y.

To the Editor:

The report supplied by the Printing Machinery Division in the December issue of Mechanical Engineering was full of interest to the writer and his only comment is upon the subdivision "Rotary Presses and Curved Plates," on page 1136, with reference to the matrix. The article describes this as consisting of several thicknesses of paper pasted together with fireproof paste. In my opinion a development in this branch was perhaps overlooked.

The above-described matrix is familiarly called a "wet mat," and while it is probably still in use by a majority of stereotype foremen in this country, the common practice in Europe as well as the tendency here is toward the use of a matrix consisting of a single sheet of specially prepared heat-resisting paper called a "dry mat."

The principal reasons for the growing use of these "dry mats" is the considerable saving in time, the convenience in handling, and the elimination of the steam table necessary for drying the "wet mat" after it has been pressed into the form by the matrix roller. It was formerly held that clearer plates might be made from "wet mats" on account of their greater plasticity, but the improved quality of the "dry mats" now obtainable renders this a moot point, with a permissible difference of opinion on both sides.

J. W. Cook.[2]

New York, N. Y.

A.S.M.E. Boiler Code Committee Work

THE Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Any one desiring information as to the application of the Code is requested to communicate with the Secretary of the Committee, Mr. C. W. Obert, 29 West 39th St., New York, N. Y.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are sent by the Secretary of the Committee to all of the members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and passed upon at a regular meeting of the Committee. This interpretation is later submitted to the Council of the Society for approval, after which it is issued to the inquirer and simultaneously published in Mechanical Engineering.

Below are given interpretations of the Committee in Cases Nos. 498 (Annulled) and 512 as formulated at the meeting of November 20, 1925, all having been approved by the Council. In accordance with established practice, names of inquirers have been omitted.

Case No. 498 (Annulled)

Case No. 512

Inquiry: Is it permissible to locate safety valves for unfired pressure vessels on the piping connected thereto, provided they conform to the requirements of Par. U-2, or is it the intent of the Code that they must be connected directly to the vessel?

Reply: It is the opinion of the Committee that the requirements of Pars. U-2 and U-6, regarding the location of safety valves, can be considered as fully met if the valves are located on the piping to the vessel, provided only there is no intervening valve or shut-off to isolate the safety valve from the vessel.

[1] Duplex Printing Press Co. Mem. A.S.M.E.

[2] G. H. Lynen & Co., Inc.

MECHANICAL ENGINEERING

A Monthly Journal Containing a Review of Progress and Attainments in Mechanical Engineering and Related Fields, The Engineering Index (of current engineering literature), together with a Summary of the Activities, Papers and Proceedings of

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By-Law: The Society shall not be responsible for statements or opinions advanced in papers or..... printed in its publications (B2, Par. 3).

Basic Science

SCIENCE vied with crime and politics for the pages of the daily papers during the holidays, when many meetings of scientific bodies were held throughout the country. The large amount of space devoted to these meetings is proof that the public is giving increasing attention to science and its influence on every-day life. It is a hopeful sign that today announcements of discoveries of scientific development are accepted as news.

One of the most interesting meetings during the holiday week was that of the American Association for the Advancement of Science at Kansas City. Here two thousand people came together to attend meetings of the thirty associated organizations for the purpose of advancing science by discussion among themselves and by the dissemination of the research results to the public. In this meeting engineering took a prominent place. It is fitting that this should be so, for engineering and science are closely related. These annual gatherings of workers in all fields of science furnish a splendid background for meetings of engineers, and an excellent opportunity for engineers to become acquainted with the developments in other fields of science.

If we regard the engineer as one who utilizes the results of the worker in basic science for the welfare of mankind, it will be obvious that the relationship between the scientist and the engineer must be intimate. The difference between them cannot be sharply defined, as in many cases the engineering work extends into the field of basic science, and in other cases the scientist may reach well into the field of the engineer. If there is a border it must, therefore, be a zone of varying width. There is another distinction between workers in science, and that is, the matter of *motive*. In his address at Kansas City, Dr. Jewett pointed out that scientific discoveries may be made with the motive of increasing the sum of human knowledge or the motive of practical application or gain to be derived from adding to the world's goods. There is a tendency among workers in science and in engineering to sharply differentiate between knowledge gained as a result of these two motives. Facts however, cannot be colored by the motive which prompted their derivation, and, however originated, they can be utilized to advance our civilization. It is important that engineers avail themselves of the opportunity to become associated with workers in all fields of science and learn what they are doing, for fundamental advances are ofttimes made by utilizing developments in a totally unrelated field. For example, a study of the temperature of lake waters by biologists and geologists furnished the basis for improved condenser-water-intake design. Here the workers in science, motivated by the desire to add to human knowledge, made a direct contribution to an immediate problem.

Section M (Engineering) of the A.A.A.S. has therefore an important function in furnishing the basis for coöperation between workers in science and engineering. Since its organization in 1919 the problem of securing the best relationship between the engineering groups and the A.A.A.S. has been given thorough consideration. Many experiments have been tried, which culminated in the successful program of the Kansas City meeting. At this meeting one day was given over to engineering papers and the evening session appeared as one of the general sessions of the A.A.A.S. with outstanding speakers having definite messages for scientists and engineers.

In addition to securing the interchange of information and acquaintanceship between workers in science and engineering, the meetings of Section M furnish a splendid opportunity for bringing together the engineers in the place of meeting in support of an important movement, namely, the advancement of science. Such coöperation of all kinds of engineers in the support of a movement which has a far-reaching effect on our mode of life and our happiness, offers many advantages to the local engineering groups. It does not conflict with the present elaborate schemes of meetings which the large societies conduct, but supplements them by bringing the leaders of thought in the border zone between science and engineering before the engineering public.

The activities of Section M are worthy of the cordial support of engineers as they furnish the contact with the A.A.A.S. The next A.A.A.S. Convention in Philadelphia, December 27 through 31, 1926, will furnish a splendid opportunity for engineers to enjoy the benefit of this contact.

The Steam Table Research

IT IS with satisfaction that we publish in the current issue of Mechanical Engineering a full report of the Progress Meeting of the Steam Table Fund. The reports of the experimenters are most interesting, and show with what care and patience the nearly insurmountable difficulties in researches of this character have been overcome. It is believed that the final results will exceed in accuracy the standard of one part in four thousand which was set forth at the first meeting of the Committee in Cambridge as the desirable accuracy to be attained in the experimental work.

Much favorable comment has been received by the committee for the public-spirited contributions of the General Electric Company in making public the first fruits of the work in the paper by Mr. J. H. Keenan. The total heat-entropy diagrams in particular have been given a wide circulation. Mention has also been made of new methods of calculation, formulation methods, and checks which will aid in the work and will be published at an early date.

Meanwhile the Joule-Thomson data are complete and will shortly be published in full. The set-up at the Bureau of Standards will shortly be in a position to function, and the work at the Massachusetts Institute of Technology is nearly ready to go into the vapor phase. Thermometric and pressure difficulties are being ironed out, and the isotherms for water in both phases from the critical point down to atmospheric pressure should be made public at the next meeting.

The policy of the Committee involves the dissemination of results and progress reports in the widest possible manner. Its members have consequently been in touch with the various European experimenters and other authorities who are interested in the perfection of our knowledge of the properties of steam. Such authorities as Dr. Rateau, Professor Callendar, Professor Loschge, and Professor Knoblauch have been put in close touch with the results that have been obtained, and it is hoped that the work in this country will be closely scrutinized and that the full benefit may be secured from experiences abroad.

It is too early at this time to prophesy regarding the completion of the work, but we may expect further publications at intervals until the entire research is completed.

The Chicago Power Meeting

THE Midwest Power Conference to be held in Chicago from January 26 to 29, 1926, is a splendid example of the manner in which engineering organizations in one locality may coöperate in the discussion of one phase of engineering that has common relations with the several branches. In this day of specialization it is the obvious trend of engineering-society activity to arrange programs that will attract those who have common interests within the profession. Recently it has been popular to associate with such a meeting an exposition of machines or apparatus illustrative of the subject matter to be discussed at the meeting. These combinations are of great value in drawing together the engineers and manufacturing executives for the public discussion of engineering problems and the advancement of engineering science. The Midwest Power Conference with its accompanying exposition and the Machine Tool Conference and Exhibition at New Haven will prove successful as annual events as long as there is an engineering need for such clearing houses of information and as long as continuing organizations are provided. The New Haven event has been carried on for four years with notable success, and there is no immediate reason to believe that the Chicago meeting and show will not bear similar fruit. Two annual meetings devoted to power have been successfully held in Chicago during January by the Chicago Section of the A.S.M.E., so the outlook for the coming event is propitious.

The Midwest Conference brings six engineering bodies into coöperation in a program that covers the field of power in its technical and economic phases. The program for the four days includes some splendid technical papers, interesting inspection trips, and addresses that point the way to the immediate future of the power industry. The meeting is designed to attract the engineers of the Middle West who are not able to attend the annual meetings of the larger engineering organizations generally held in the East. In planning for this purpose, the Chicago committee is to be heartily congratulated for its splendid enterprise in providing an elaborate meeting within easy reach of a large number of engineers who welcome the opportunity to meet for the interchange of experience and information. The coöperating organizations are entitled to a successful outcome after the expenditure of the large amount of effort necessary for the planning and conduct of an event as elaborate as the one to be held.

Governmental Reorganization

THE American Engineering Council is carrying on a movement for the reorganization of the Department of the Interior in coöperation with the representatives of engineering and allied organizations. The plan for the reorganization calls for the change of the name of the Department of the Interior to the Department of Public Works and Domain and a revision of the administrative functions of the Government dealing with public-works activities whereby they will be coördinated and made more efficient. The plan is to be introduced into Congress by Senator Wesley L. Jones from Washington and Representative Adam M. Wyant from Pennsylvania, and has the approval of Secretary Work and Commissioner Mead of the Reclamation Bureau.

Under the reorganization scheme advocated by the engineers, the Bureau of Public Roads, now in the Department of Agriculture, and the Office of the Supervising Architect, now in the Treasury Department, would be transferred to the new Department of Public Works and Domain.

The Rivers and Harbors Improvements, Mississippi River Commission and California Debris Commission, at present under the jurisdiction of the War Department, would go to the new Department together with the Office of Buildings and Grounds, District of Columbia; the Superintendent of the State, War, and Navy Department Buildings, the Rock Creek and Potomac Parkway Commission, and the Office of the Architect of the Capitol.

The Board of Road Commissioners for Alaska would be abolished and its duties performed by the Secretary of Public Works and Domain.

One interesting feature of the bill is a provision that the engineering officers of the United States Army may be detailed by the Secretary of War to non-military duties having to do with river and harbor improvements, the Mississippi River Commission, the California Debris Commission, or other civil functions with the approval of the Secretary of Public Works and Domain.

Safety in Industry

SCATTERING realization of a grave situation seldom reveals its true seriousness, nor does it often lead to the correction of such a situation. National problems become grave under just these conditions, for they grow until their magnitude forces the attention of influential individuals and organizations, and finally that of the public.

It was not so long ago that America awakened to the fact that her natural resources were being wasted—and had been for years—in a prodigal manner. While the counteracting movement, conservation, came late, it did not come too late to save some of the most valuable resources, and to assure that watchful care shall be exercised hereafter in the choice and use of materials in industry. But the extent of the wastage of time and money that accidents are responsible for is not generally understood.

War is destructive, and while the waste of materials in war causes but little concern, the unavoidable waste of human life always causes widespread sorrow, gets universal attention, and is never forgotten. Industry is constructive. Waste of materials is bewailed in industry. Realization of the mounting toll of lives and wealth due to accidents was followed by the nation-wide cry of "Safety First." But the public awakening, while sudden, is not yet complete, even among engineers.

Dr. William F. Durand was so convinced of this that one of the last of his important acts as President of The American Society of Mechanical Engineers was to bring the situation to the attention of the members of the Society in a very unusual way at the Annual Meeting in New York. The statement issued by him was in itself startling and will bear repeating here.

> The accident situation in this country has reached appalling proportions, taking an annual toll of approximately 80,000 lives, while disabling over 2,000,000 more for varying periods. This yearly loss is greater than that sustained by our armies during the entire period of the World War, and has become still more serious in several of its aspects.
>
> Compared with other nations, there are killed in peaceful America per million of population almost twice as many as in France or Japan, more than twice as many as in Great Britain, and four times as many as in Denmark.
>
> The direct loss has been estimated to run each year into the billions of dollars, while the indirect loss is beyond calculation, and our country is now confronted with a problem, already sufficiently grave, which may ultimately prove to be the greatest in its history.
>
> Additional to and dwarfing all such losses, however, are the human suffering and misery engendered, the extent of which none can either measure or conceive, but which must exert an increasingly retarding effect on the advancement and uplift of our country and bring a stain upon it which can never be effaced.
>
> The members of this Society, therefore, in recognition of the situation, which calls for the best efforts of every citizen having the welfare of our country at heart, pledge themselves and this Society to continued and unremitting effort in this greatest of all human endeavor—the work of accident prevention.

This statement, startling as is its content, was given redoubled force by the manner of its presentation at the Meeting. On one of the mornings it was read at every session by the chairmen, and after its reading one minute of silence was observed. It proved to be a long minute of sober realization. At the same time there undoubtedly were born in the minds of many engineers plans which will rapidly develop to check waste of humanity.

Registration of Chemists

IN THE January issue of *Industrial and Engineering Chemistry* an interesting situation is revealed about the increase of foreign-trained chemists in the plants of the American chemical industry. An editorial on this subject points out the need for protecting American chemists and thereby safeguarding American industry. The editorial advocates the registration of alien chemists. The plan of registration is, in part, as follows:

> The registration of such aliens would greatly assist in eliminating the unfair competition to which our scientists may become subjected, and would

be equally useful in many other circumstances. The increase in labor entailed in carrying out such work would not be important, and the mere fact that all visitors are required to register in some detail would deter many from attempting to take advantage of this country's hospitality.

Some of these men are doubtless well trained, but many of them have been found to be inferior to the American chemist. They are unacquainted with costs of American living, and in order to get a foothold are willing to take as an entrance salary a sum which is but a fraction of that being paid to the American chemist.

Industry will eventually find this procedure costly and unsatisfactory. A few good men may find their way into American industry, but in the long run they will save their employers nothing. Meanwhile we are confronted with the necessity of protecting American chemists.

Tolerances and Allowances for Metal Fits

DURING December, 1925, the American Engineering Standards Committee approved as a Tentative American Standard the report on Tolerances, Allowances and Gages for Metal Fits. This report is the product of the Sectional Committee on the Standardization of Plain Limit Gages for General Engineering Work, organized under the procedure of the American Engineering Standards Committee in June, 1920, by The American Society of Mechanical Engineers, acting as the sponsor body. The scope of the project as published by the A.E.S.C. is "Nomenclature and classification of machined fits, including allowances and tolerances, for interchangeable manufacture; classification and fixing of standard tolerances for plain limit gages; methods of gaging these classes of fits." The present report is the first which the Sectional Committee has planned to present. A second will cover methods of gaging and the standardization of gages.

In announcing the new standard, Dr. P. G. Agnew, Secretary of the American Engineering Standards Committee, issued a statement which calls attention to the fundamental importance of this report as an aid to greater economy in manufacture. A portion of his statement follows:

The economy of interchangeable parts was a lesson taught by the war. It will probably be remembered that one of the triumphs of American manufacturing was the production of parts for machine guns and other arms which were so completely uniform that perfect guns could be assembled from piles of thousands of parts mixed together without the necessity of any fitting work. This procedure at once established the production of arms on an enormous scale, and yet at a very low cost per gun.

Exactly the same principle holds true with the manufacturing of other articles. For example, a wheel intended for a one-inch shaft made by one manufacturer should fit upon the one-inch shaft made by any other manufacturer. Under present conditions, however, this perfect fitting is rarely realized. The reason is that the wheel manufacturer bores the one-inch hole in accordance with one set of gages, while the manufacturer of the shaft uses a set of gages based on a different system. In consequence one piece may be either a trifle too large or too small for the other, with the result that the wheel will either not go on the shaft at all, or else it will fit too loosely. If, however, both manufacturers had used nationally standardized, and therefore uniform, gages for determining the dimensions and had used these gages in precisely the same way, perfect fitting would be assured, no matter when and where the two parts had been manufactured.

Certain American manufacturers have been following well-considered systems in their own works for many years and have been able to produce their parts in large quantity for use either for the assembling of new machines or for the repairing of old machines, without further fitting. It was in order to unify these methods into a nationally uniform system and thus to extend the benefits to all American manufacturers who could use it, that the American Engineering Standards Committee undertook the work leading to this report on machine fits in interchangeable manufacture.

This report provides a classification of the various kinds of fits from the loosest as used in agricultural machinery and similar equipment, to the "force or shrink fit" where, instead of fitting easily, the parts are pressed together under enormous pressure so as to be rigidly attached to each other and to stay there through severe use, as with a locomotive wheel and its tire.

Much technical knowledge and experimentation were required to set up the table of fits. The clearance or play required between small parts, such as the shaft in a sewing machine and its bearing, is very different from that required for parts of a large rock crusher or a hoisting engine, and careful study was needed to work out a scheme of allowances that would cover the entire range.

It is to be hoped that all manufacturers engaged in making products with interchangeable parts will adopt the new standard so that uniform national practice based on the best of knowledge may be reached and maintained. This will result in enormous savings in labor and material, which will permit production of any given part on the largest possible scale, and will serve the customer directly by permitting quick and certain replacement of worn or broken parts.

In fact, it has been estimated that the general use of this new "key" to mass production will mean a saving of at least one billion dollars a year to American manufacturers.

The Sectional Committee which prepared the report was made up of twenty-one engineers and experts in interchangeable manufacture. Eugene C. Peck of Cleveland served as Chairman, Luther D. Burlingame of Providence as Vice-Chairman, and Henry W. Bearce of Washington as Secretary.

Copies of the report may be purchased from The American Society of Mechanical Engineers or from the American Standards Committee at 29 West 39th Street, New York, N. Y.

Promoting the Use of Specifications

AS A NATURAL development of the classification and publication of approximately 27,000 American specifications in book form with the title National Directory of Commodity Specifications by the Bureau of Standards, Department of Commerce, a plan for the promotion of the use of specifications in industry has been advanced by Dr. George K. Burgess, Director of the Bureau. This plan, known as the "Certification Plan," is outlined below.

Notwithstanding the immense amount of time and labor represented in the formulation of specifications, the fact remains that many excellent specifications well recognized throughout industry are not being widely used at the present time because of the inability on the part of most purchasers to determine whether or not commodities delivered correspond to the specification requirements. A great impetus to the popularizing of the use of specifications could be given by eliminating this disadvantage to the small-quantity purchaser.

As a solution to this problem, it has been proposed to have the seller certify that the commodities delivered have been *tested by him* and found to comply with certain well-established specifications.

Such benefits as are now derived from the use of specifications by large consumers would be made immediately available in full measure to the small consumer, with the incidental advantages to the larger consumers of convenience in ordering and accepting commodities and of lessening the price by reason of the broadening of the field of supply.

Probably such letters as those outlined herewith would produce the results hoped for by numerous purchasing agents who are desirous of making use of certain admittedly advantageous specifications but are not doing so because of the lack of information as to manufacturers willing to supply commodities meeting these specifications.

It has been suggested that such letters could be circulated in the manner indicated with great benefit to all persons concerned, and without encountering any of the difficulties that would surely arise if an attempt were made to give publicity to a list of "trade brand" or other manufactured commodities complying with well-established specifications, or even to supply a list of manufacturers whose commodities have been found to comply with the specifications.

Among the duties assigned to the Federal Specifications Board are not only the compilation and adoption of standard specifications for materials and services, but also the bringing of the Government specifications into harmony with the best commercial practice whenever conditions permit, bearing in mind the broadening of the field of supply.

Encouraging the maximum possible number of purchasing agents to make use of the specifications of the Federal Specifications Board would broaden the field of supply by including the maximum possible number of producers to manufacture commodities meeting the requirements of the Federal Government. Moreover, the widespread use of specifications of the Federal Board would serve to draw attention to such modifications as might well be made therein in order to render them satisfactory to the buying public, and to bring them into harmony with the best commercial practice.

Reference is made herein specifically to Federal Government Master Specifications, as the proposed form letters relate to a list of manufacturers willing to certify that certain commodities made by them comply with these specifications. However, the plan outlined could readily be applied to other groups of nationally recognized specifications.

The American Engineering Standards Committee discussed this subject at a recent meeting when it was presented by Dr. Burgess. The comments of our readers will be very welcome.

Kansas City Meeting of the A.A.A.S.

Splendid Program Included Outstanding Addresses on the Relation of Science to Engineering, on Coöperation between Industries and Universities, and on the Value of Research to Industry

SCIENCE prevailed in Kansas City from December 28, 1925, through January 2, 1926, during the Annual Meeting of the American Association for the Advancement of Science. This organization comprises about fourteen thousand individuals and provides for the coöperation of the numerous American scientific societies. It offers the means by which these societies may unite for the broader and more general activities that are directed toward the progress of knowledge as a whole and toward its increased appreciation by the general public. The association works for the advancement of science and all that that phrase broadly implies.

At the Kansas City meeting thirty organizations met simultaneously in the fields of mathematics, physics, chemistry, astronomy, geology, geography, zoölogy, botany, anthropology, psychology physiology, scientific history, engineering, medicine, agriculture, and education. Two thousand enthusiastic workers and students in science registered at the meeting and participated in the splendid program, which this year contained much of interest and value for engineers.

In addition to the sessions of the coöperating organizations, there was a series of general sessions which gave an opportunity for those present to learn of outstanding results obtained in scientific work in several fields. The opening session, which was presided over by Dr. M. I. Pupin, president of the A.A.A.S., was given over to the address of the retiring president, Dr. J. McKeen Cattell, editor of *Science,* and entitled Some Psychological Experiments. He traced the development of psychological investigation and emphasized the increasing value of psychology as a working science. The second general session was devoted to the address of Dr. Dayton C. Miller, professor of physics in the Case School of Applied Science and president of the American Physical Society, on the Michelson-Morley ether-drift experiment, its history and significance. For this address Dr. Miller received the annual A.A.A.S. prize of one thousand dollars which is awarded each year to the author of a notable contribution to the advancement of science presented during the annual meeting. President F. D. Farrell, of the Kansas State Agricultural College, presented the fourth annual Sigma Xi lecture at the third general session. His address was entitled The Desert Becomes a Garden. Prof. James Pierpont, of Yale University, was the speaker at the fourth general session. He dealt with the history of man's effort to solve the problem of space, and the effect of relativity on our views. This was the third annual Josiah Willard Gibbs lecture, presented under the auspices of the American Mathematical Society. The fifth general session was given over to the engineers, and is referred to more fully later. The sixth session was devoted to a discussion of research under the auspices of the A.A.A.S. Committee of One Hundred on Scientific Research. Dr. William MacDonald spoke on the intellectual worker and his work. Dean Byron Cummings gave an address on the problems of the scientific worker, and Dr. Frank E. E. Germann spoke on coöperation among college and university workers. The program for the last general session consisted of an address by Austin H. Clark on the Smithsonian Institution, its function and its future.

A feature of the Kansas City meeting was a series of popular complimentary lectures for the citizens of Kansas City. Among the topics presented were earthquakes, the structure of the atom, scientific education, the origin and evolution of worlds, the amplification of heart sounds, and the beaver, a study of animal intelligence.

Two groups of sessions were of particular interest to engineers. Section M (Engineering) of the A.A.A.S. conducted a program on Wednesday, December 30, arranged by Dr. Charles Russ Richards, president of Lehigh University, and chairman of Section M, with the coöperation of the Kansas City Engineers' Club. N. H. Heck, of the U. S. Coast and Geodetic Survey, is secretary of the Section. The Section Committee consists of representatives of engineering societies and four members at large. The first number on the program on Wednesday morning was the address of the retiring chairman of Section M, Dr. A. E. Kennelly, which discussed the advancement of engineering in relation to the advancement of science. This address appears as the leading article in this issue of Mechanical Engineering. The other speakers of the morning were E. Lester Jones, who dealt with the relation of map making to the progress of modern civilization, James B. Macelwane, who related the contribution of seismology to engineering design, and Hugh Miller, who spoke on human engineering.

The afternoon program, which was prepared by the Kansas City Engineers' Club, was presided over by John Lyle Harrington, Past-President A.S.M.E. and member of the Section Committee. The program consisted of the three following papers: Mapping Methods Used in The Third Asiatic Expedition to the Gobi Desert, by Lee B. Roberts; Synthetic Gasoline as a Motor Fuel, by Roy Cross; and Recent Developments in Airplane Mapping by Photography, by Major Cleveland C. Gee.

Over four hundred engineers gathered at dinner at the University Club preceding the evening session, which was one of the general sessions of the A.A.A.S. meeting. Dr. M. I. Pupin presided at the session in the auditorium, which was filled with a splendid audience. The first address was by Dr. Frank B. Jewett, past-president A.I.E.E. and director of the Bell Telephone Research Laboratories, and dealt with the various kinds of research and their interdependence. It appears in abstract form below. The second address was by Dr. William F. Durand, Past-President of the A.S.M.E., who spoke on science and engineering. His address will appear in a later issue. S. C. Lind spoke on the needs of the modern chemist.

Section K of the A.A.A.S., on the Social and Economic Sciences, conducted a symposium on research which extended through six sessions during three days and at which twenty-three papers were presented. The importance of research in industry was emphasized in these papers, which form a stimulating addition to the literature of scientific research. Space is not available here for even abstracts of all of these contributions, but generous extracts from five which are of particular interest to engineers follow the abridgment of Dr. Jewett's address given immediately below.

Motive and Obligation

Engineering, Industrial Research, Research Without Utilitarian Objective, and the Interdependence of the Fields to Which They Pertain

By FRANK B. JEWETT,[1] NEW YORK, N. Y.

DURING the past ten years a remarkable volume of literature has grown up testifying in various ways to the practical, that is, the industrial, value of research. Running over this literature one is impressed by the wide range of industries which have gone on record in one way or another as believing in the value of scientific research, each in its own field. All branches of the electrical industry and all branches of the chemical industry are present of course, since they are lineal in descent from the research laboratory, but in addition there are countless others ranging from scientific agriculture to tanning and from metallurgy to glass-making.

To me the scientific discoveries which connect the world of knowledge acquired for its own sake with the world of men's daily existence are like the connecting links of an intricate chain network. From one side radiate chains, long and short, simple and complex—frequently cross-connected, but all extending into the region where the forging of each link had back of it the *motive* of increasing the sum of human knowledge. From the other side

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stretch out other chains, also long and short, simple and complex, and likewise frequently cross-connected, but all extending into the region where the forging of each link had back of it the *motive* of some practical application or the gain to be derived from adding to the world's tools.

Two things there are which are common to the patterns on the two sides of these connecting links: (1) The patterns are each composed of links capable of forming chains, though some may not yet be connected; and (2) the artisans who fashion the links have a common equipment of mental and physical tools and of methods. Change only the element of *motive* which directs their link forging and you automatically transfer the artisan from one field or pattern to the other.

The connecting links which lie at the border where motives change may be forged by artisans in either group. An artisan seeking to add a link to his chain of discrete knowledge may find it extending across the boundary toward some practical human requirement. More frequently, perhaps, an artisan seeking a starting point from which to forge a useful chain to some desired objective may see across the border the terminal links of the chains he needs for his anchorage.

All Industries Benefit about Equally from Progress of Science

There is another phase of the whole matter of the interdependence of engineering, of research with the industrial *motive*, and of research with the extension of knowledge motive. Considered on a broad basis, there are good grounds for believing that all industries benefit about equally from the progress of science. So extensive are the interrelationships between our industries that alternating times of depression and prosperity pass over practically all of them at the same time. If each industry went its course independently of the others such a phenomenon could hardly occur. So it is with the spontaneous economic distribution of the benefits of science—they reach practically all industries, and in proportion to the size and the importance of each. This notwithstanding the fact already noted that the benefits of science appear on the surface to have influenced certain industries more conspicuously than others. In cases where the benefits are indirect and therefore least conspicuous, they are even more difficult to measure in terms of dollars and cents, but are none the less real.

To the farmer the study of scientific agriculture, research in the field of plant physiology, in soil chemistry, etc., has brought many direct benefits. But to the fertilizer industry these researches have been of immense value as indicating what substances should be added to the soil under any given set of conditions, and what are periodically removed by the harvesting of crops and must therefore be replaced artificially if the value of the soil is not to deteriorate. To the railroads, likewise, the scientific and exact study of agricultural conditions is conferring many indirect benefits, by increasing the yield of adjacent farm lands, by extending the variety of crops produced, by raising the purchasing power of the farmers with resulting increases of inflowing freight.

Let us look at this matter of indirect benefits in a slightly different way. One very simple measure of the advance of our material civilization is found in the extent to which we employ the structural metals in catering to our daily requirements. In 1883 the amount of aluminum recovered in metallic form in this country was 1000 ounces, valued at $875. In 1923, or forty years later, the output was 90,000,000 lb., valued at $28,000,000. The growth in the aluminum industry has been based directly upon research in chemistry and electricity. In 1883 the output of copper was about 52,000 tons, valued at $18,000,000, while by 1923 these figures had grown to 715,000 tons at $210,000,000. Taking into account the doubling of population during this forty-year period, we find that the per capita use of copper has increased sevenfold. As the bulk of this copper has gone into the electrical industry, which in turn is largely the child of pure science, we have here very clear evidence of how great the indirect benefits of research may be.

In directing your thoughts along these lines, I am not overlooking the fact that the metal-producing industries, and in fact practically any large industry you care to name, have received direct benefits from scientific research. But over and above these, and certainly ranking equally with them in importance, are the indirect benefits distributed through the agency of industrial coördination, with the result that what benefits one industry benefits many others. This means that not by particular industries, but by all industries, and as a people, we should enthusiastically acknowledge the practical value of scientific research. And in this acknowledgment let us bear in mind that there are a few fundamental principles never to be lost sight of.

No Way by Which Usefulness of Scientific Discoveries Can Be Immediately Appraised

One principle is that frequently the practical value of a scientific discovery may not be revealed until long after the original research has been performed, and then perhaps in another field of science. This is an important point and one which deserves frequent repeating, for as we meet with added success in turning scientific discoveries to practical account, we are confronted with a strong temptation to seek knowledge because it is useful, and not simply for the sake of knowledge itself. We are thus in danger of losing the true perspective, for it becomes increasingly easy to pass from seeking knowledge because it is useful to seeking what we may consider, from a priori reasons, to be useful knowledge. I am positive that no touchstone has been vouchsafed us by which we can at once determine even the approximate usefulness of scientific discoveries made in the quest of a broader knowledge.

Time Lag between Pushing Forward of Frontiers of Knowledge and Its Application

Another important principle pertaining to the relation between fundamental and applied science and engineering concerns the matter of time lag between the pushing forward of the frontiers of knowledge and the application of this knowledge by the engineer. The application of electric motors to rapid transit began almost immediately after the installation of the early generating stations; the application of the same kind of motors to the power shovels and other devices employed in mining coal and iron, are matters of the most recent record. The indebtedness of rapid transit to electrical research is very obvious and has been recognized for years. The similar indebtedness of mining is hardly yet recognized.

In closing, let us look for a moment in a somewhat different way at the reverse of the picture we are scanning. We have seen a world, every item almost of whose material well-being and progress is dependent on some direct or indirect use of knowledge gained through scientific research. It is a world which looks each day more and more to what we might term the forests of science for the stuff it requires for its new structures.

For more than a hundred years now this lumbering operation has been developing with every increasing acceleration. The trees of the forest of whatever age are for the most part like real forest trees in that they have grown where nature willed. Man, the user, has taken what he found with little thought of the morrow, so far as adding to the forest was concerned. While lumbering in our scientific forests differs from lumbering in our more material forests, in that we do not destroy the trees we use, we are, nevertheless, always in need of new and untouched trees. I think it is fair to say that despite its remarkable growth, the reserve of unused trees in our scientific forest is less in relation to our needs now than it was fifty or one hundred years ago.

Common prudence and a decent regard for the welfare of our children and our children's children should impel us as sagacious lumbermen to foster the growth of new scientific trees and to cultivate as well as to use the forests we now have. Each succeeding generation is entitled to a supply of new timber as great in proportion to its needs as that enjoyed by preceding generations.

But how are we to foster this greater growth? True, we cannot predetermine new kinds of scientific trees (or links and chains, if you prefer my earlier simile), or even the places they will grow. What we can do, however, is to keep our eyes open and cultivate so far as we are able, every bit of ground which gives promise of growing new trees or better trees of the old stock. Above all we can see to it that those who have it in them to produce new trees or to cultivate old ones to a better growth are afforded every reasonable facility to continue in the field for which they above others are fitted.

History has shown over and over the enormous sacrifices those

who have the God-given faculty are willing to make in their quest for extending the bounds of knowledge. That the world is poorer because many have had to succumb to the demands of life and family, which transcend all else, we are sure.

Research—the Prime Mover of Industry

BY MAURICE HOLLAND,[2] NEW YORK, N. Y.

WHEN Faraday demonstrated the discovery, in pure-science research, of the fundamental principle of electromagnetic current before the Royal Society, some one in the audience said, "All very nice, but what use is it?" "Perhaps some day you can tax it," Faraday replied. That was nearly 100 years ago.

In 1925 one of the largest manufacturers of electrical machinery in the United States paid an income tax of over $7^1/_4$ million dollars. What factors enter into this "time lag" of a 100 years from the discovery in pure science to the mass-production application in industry?

There are three fundamental principles in the relation of applied science or research to industry. The first is the period in the development and growth at which research is introduced and the consequent acceleration in the progress of that industry. The second is the "time lag" in the research cycle, as it affects specific industries. The third is that five factors, characteristic of the industry itself, very definitely govern the development of research in that industry.

One hundred years ago industrial supremacy was largely a matter of the control of raw materials. Within the last 25 years a new factor called "research" has considerably altered the foundations of the industrial structure.

Industrial research is a predominant force today, since it creates industries and even destroys them—destroys them in that it revolutionizes present processes, invents new ones, and is therefore a principal motivating force in industrial progress.

PERIOD OF INTRODUCTION OF RESEARCH IN AN INDUSTRY OF FUNDAMENTAL IMPORTANCE

That the period of the introduction of research in an industry is of fundamental importance, I need but to refer to the comparative growth and development of two of the older industries, such, for example, as the fisheries, in which the production methods prevailing today are identical with those used in the Biblical story of the Sea of Galilee, and the textile industry, which is one of the oldest arts known to man, and experienced a rapid development through invention during the period 1725–1775.

In comparison with this I can name five industries which have attained their full growth from the basic invention or discovery to mass-production application in less than 50 years. They are electric illumination, radio, motor-car, electrochemistry, and the telephone.

The reason for this phenomenal growth is obvious when it is understood that the five factors which govern the relation of research to industry include the rate of growth and development of the industry itself, its inherent technical nature, the character and number of technical personnel employed, the position in foreign trade, and the character of production processes and present research facilities. In the five industries which have been developed in less than 50 years there are encompassed from three to five of the factors which govern the development of research in an industry.

The electrical industry which has assumed the proportions and occupies the place that it now has, has done so in a period of 43 years. The first central station was opened in 1882 by Edison in Pearl Street, New York. The electrical industry is representative of that type of industry which has taken full advantage of research organization. Three of the largest concerns in this industry—the General Electric Company, the Westinghouse Electric and Manufacturing Company, and the American Telephone and Telegraph Company—are spending about one-fifth of the total amount spent for research in the United States.

THE RESEARCH CYCLE

This industry follows closely the pattern of what I have chosen to call the "research cycle" in each successive stage, beginning with "pure-science research" as the first stage in the cycle. This is represented by the discovery of current electricity by Volta in 1779. Working in "applied science," Sturgeon utilized this observation and constructed the first electromagnets in 1825.

Entering the period of "invention," Faraday, based on his inventions in pure science, constructed the first dynamo in 1831, which was later destined to "electrify" the world.

The period of "industrial research" is associated with the theoretical work of the physicists Gauss, Weber, Rowland, and Hopkinson.

"Engineering development" is linked with the name Siemens, and the product of the combined labors, theoretical and practical, with the production of the shunt-wound, the Gramme and drum armatures, as well as the multipolar machines.

It remained for Edison to make the "industrial application" by establishing the first central station in 1882.

With the dawn of the era of industrial research as an accepted industrial-aid tool in 1890, a new generation of engineers, well versed in physics and mathematics, mastered the use of alternating current, and to them belongs the credit for the rapid development of transformers, synchronous and induction motors, and the huge alternators of the present day. Thus in the short span of 43 years the electrical industry has grown from a single plant to an industry having a book value of 25 billion dollars and a generating capacity of 20 million horsepower.

In a similar fashion several of the younger industries mentioned follow closely the research cycle in each of its successive stages; pure-science discovery, applied science, invention, industrial research, industrial application, standardization, and mass production.

TIME LAG IN THE RESEARCH CYCLE

What evidence have we to submit in proof of the relation of research to industry and the fundamental conception of time lag in the research cycle?

Many may have occurred to you. I submit these:

First, all five industries, the radio, electrochemistry, electrical illumination, telephone, and motor-car, are inherently technical in nature, employing large numbers of technical personnel, have had a rapid development and growth, and use production processes which are dependent upon technical knowledge rather than skill. At least two of these industries, electrochemistry and radio, were virtually created in a research laboratory. Two others, the automobile and the electrical, have taken first and third place, respectively, in importance and size with contemporary industries in less than 50 years. By comparison, for the two oldest industries, the fisheries and the textile, there is little to be said, although it is at once apparent that in the first place it has taken centuries to accomplish in these industries what has been done with the aid of research in decades in the first group.

These industries, until comparatively recent times, were arts as distinguished from science, dependent upon skill rather than technical knowledge, employed artisans rather than technicians, and were further handicapped by tradition, prejudice, and human frailties handed down from generation to generation. Processes and tools were the products of skilled practical workers and mechanics. It is interesting to note that neither of these industries contains a single factor which has been identified as fostering the growth of research in an industry.

VALUE OF RESEARCH TO AMERICA'S LARGEST INDUSTRIAL CONCERNS

The major aspects in the comparison have been brought into relief at least to an extent from which you can reconstruct the picture on the canvas of your own background and draw your own conclusions. But what does all this mean in terms of present-day industrial development and its relation to industrial research? Brought down to date, at least to the last income-tax period in 1925, the relative growth and development, as well as the earning capacity of representative industrial companies, is reflected in the published statistics of tax paid by the ten largest ones in America.

If you will scrutinize this list, you will be impressed at once with the fact that among the first ten are names which are synonymous

[2] Director, Division of Engineering and Industrial Research, National Research Council.

with large and completely organized research departments. These companies include the Ford Motor Car, American Telephone and Telegraph, United States Steel Corporation, General Electric, General Motors, Standard Oil, New York Central, Consolidated Gas, Union Pacific, and Reynolds Tobacco Company.

Eight of the first ten have as an essential part of their production units, research laboratories of international reputation. The total income tax paid by these ten concerns is approximately 75 million dollars, or three-quarters of the aggregate expenditures for research in the United States.

In these figures we see the final appraisal of the value of research, a real measure of industrial progress, the ultimate stage in our research cycle, and an indicator of the speed at which the main rotor in the prime mover is turned.

The Frontiers of Industry

By EARL P. STEVENSON,[3] CAMBRIDGE, MASS.

THE field for useful inventions in the arts is kept fertile by new scientific discoveries, and never more so than today, with the quickening rewards of continued attack on the very substance of matter. What new opportunities for achievement lie beyond the present frontiers of our scientific knowledge should not, however, be our only concern. The frontiers of science are further flung than those of industry; we must appreciate this fact and quicken our pace lest we pay further and greater tribute to those nations whose people have come to realize the great industrial opportunity that awaits a fuller appreciation of data already before us. We have passed through a period of epoch-making discoveries; if we are to more completely realize upon their potentialities our recourse is intensive research, wisely directed, adequately financed, and sustained in the face of obstacles. To better cope with this situation, more energy should be concentrated on the frontiers of our industries.

Possibly we are too much concerned with the evolution of industries, in effecting minor improvements in old processes, and underemphasize in our research programs the opportunities for revolutionizing our practice of these processes. Living in the midst of abundant natural resources, we are not as responsive and sensitive to the significance of certain scientific observations in affording the suggestion of a new process as certain less-endowed nations. We have so far been content, for example, in the exploitation of our petroleum reserves. But this situation will change. We are coming to appreciate more the necessity for intensive research, as opposed to the extensive.

Research, which gave to Germany her prewar monopoly of dyestuffs and to which she looks for her economic rehabilitation, is too often viewed apart as an ultra, rather than an intra, activity. The needs of research for financial support deserve recognition more on a par with the other agencies and divisions which comprise the machinery of production and distribution. In the face of millions for advertising products by slogans in the absence of the distinctiveness in quality or utility which research alone could provide, research expenses are properly listed by the accountant among miscellaneous and sundries.

Price Paid for Failure to Recognize Value of Research

We have already paid the price of our failure to recognize the earning power of research. But a very few years ago the American rights under the viscose patent for artificial silk went begging in this country for $50,000, and last year witnessed the production in this country of 36,000,000 pounds, valued at eighty-one million dollars, our tribute to a foreign-owned corporation that had the vision and faith necessary to finance this project through its development stages.

However parsimonious we may be in supporting fundamental industrial research, millions flow freely into the design of new and improved machinery for the operation of old processes. Examples without end could be cited where money has been liberally spent on machine design. A hundred thousand dollars to make a paper lard bucket in an automatic machine for your butcher's edification shows laudable enterprise. In the meantime, our more imaginative competitor has conceived an entirely new type of lard and ice-cream pail—a paper can formed directly from pulp, so our one hundred-thousand-dollar machine is idle most of the time, and is fairly on its way to the museum.

Research Should Be Placed on a More Even Competitive Basis with Labor-Saving and Mass-Production Projects

A way should be found to place research which aims to better utilize energy and materials for our daily use, and is more concerned with primary processes, on a more even competitive basis for financial support with those projects which promise a more immediate return by effecting labor savings and larger-scale operations in standard processes. This cause is undoubtedly advanced by such publicity as has been given the much-heralded new German process for making methanol from blue water gas. As the wood-distillation industry in this country faces the possibility of losing its investment—which has been estimated at $100,000,000—it at last sees the handwriting on the wall. A few years ago, it is reported, an expenditure of $8000 a year was vetoed by the directors of one of these concerns in this country. The action, from one angle, was a proper one. The sum was entirely inadequate; but a request for $50,000 a year would never have had a hearing. The scheme would have been branded as visionary, and the perusal of the current balance sheet would have continued with much discussion of accounts receivable versus those payable, for the auditor is a member in full and regular standing at these directors' meetings.

Two typical and nationally important research problems such as comprise the frontiers of our industries are the carbureting of blue water gas and the production of synthetic rubber. Instead of a guerilla attack, involving casual work here, duplication there, and general chaos, the great opportunity of organized research, ably directed, sufficiently financed and sustained in prosecution, is evident. Such an enterprise requires imagination, courage, and faith in its sponsors. It is a most attractive speculation.

This situation is a factor in the recent organization by several of our large enterprises of research corporations, directed to a more intensive study of their problems; another phase is the separately organized and privately financed research syndicate which has as its objective the establishment of a new industry through a research accomplishment. The adaptability of such latter projects to a better utilization of our natural resources is advanced for your consideration.

The initiative of such enterprises is not hampered by traditions nor fettered by short-sighted conservatism. The spirit that pushed the railroads across the last of our territorial frontiers can again function, this time on our industrial frontiers. We must speed up, and as Delmar has truly said, "Industrial research is accelerated experience."

The Administration of Industrial Research

General Observations in the Application of the Industrial Fellowship System 1907–1926

By EDWARD R. WEIDLEIN,[4] PITTSBURGH, PA.

THE philosophy of scientific research is that no one can succeed in laboratory experimentation without benefiting his fellowmen. If a research laboratory is founded, it is because there is need for it, and it will bring public benefit.

Prior to establishing an industrial-research laboratory in their organization, the company executives should believe in the realizable possibilities of research, should intend to give it proper financial and moral support, should know what to expect from it, should have determined whether to try a comprehensive and thorough type of research or to limit the work to a narrower study of specific problems as they arise, and should be prepared to give sufficient time to put the laboratory well on a sound basis. The laboratory director, if properly chosen—and great care is needed in selecting

[3] Research Director of Arthur D. Little, Inc.

[4] Director, Mellon Institute of Industrial Research, University of Pittsburgh.

him[5]—can be relied upon to do the rest, but he should be aided in launching the work correctly, and in maintaining suitable facilities and staff for attending to all scientific research of the company.

Industrial history makes it clear that happy ideas and chance discoveries have not contributed materially to the progress of technology. The stimulus for development generally results from demand, and in manufactures organized on modern lines the working out of new processes and the improvement of existing processes consist mainly in the application of scientific fact and theory, the raw material of the applied scientist and engineer. Industry, therefore, should sustain pure as well as technical research, not merely for altruistic reasons, but because pure-science research makes for progress in technology. The successful director of industrial research is a Janus, one of whose faces receives the impressions from technology, while the other is turned toward the laboratories of pure science.

Scope of Research Management

Until about ten years ago, research-laboratory management was commonly regarded as an empirical matter, mastery of which could be attained only in actual practice. Gradually, however, the organon of scientific management, with its division of work, systematic planning, and use of recorded experience, has been examined in the laboratories of science, and its methods are now permanent features of every research laboratory of importance. It is evident that there are a number of fundamental principles in directing research, a clear recognition of which is just as helpful to laboratory executives as is a knowledge of underlying economic principles and influences in any other line of endeavor.

The field of research-laboratory management covers the following functions:

1 Definition of policies
2 Organization for operation
3 Planning work, and
4 Direction of activities.

This management aims to correlate the details of laboratory operation so that the work will proceed harmoniously and productively toward the desired goal. It is essential both for controlling operation and for acquiring administrative information for future development.

Definition of a Research Organization

A research organization is a body of scientists that are combined through system and regulation into a coördinated whole. Every successful research-laboratory director is an organizationist, a believer in the smoothly operating machine of management. All of his research men work together for a common end.

The value of direct coöperation, or concerted team work, among the members of a research laboratory cannot be overemphasized. There should be no tendency toward purely individualistic work; an appreciation of the importance of mass action in achieving results should be firmly established from the start of activities.

No research man is a complete unit of himself. He requires the contact, the stimulus, and the driving power that are generated by his association with other research men, in his own organization, as well as at meetings of professional societies.

Principles of Research-Laboratory Management

The principles of research-laboratory management may be given briefly as follows:[6]

1 The systematic use of experience, to develop a local science
2 The scientific selection of research men
3 The economic control of effort; and
4 The promotion of personal efficiency, by education and development of research men, and by inducing close, cordial coöperation between the management and the men.

The primary fundamental in research laboratory management is the mental attitude that consciously applies the transference of knowledge and skill to all the activities of scientific investigation. The regulative principle of research management along sound lines includes four important elements,[7] namely,

1 Planning of all experimental work by conferences between research men and management
2 Functional organization by which each research man is responsible for a single line of effort
3 Training all employees so as to require them to do each piece of work in what has been found to be the best method of operation; and
4 Equably fair payment of all employees, based on type, quality, and quantity of output.

Selection of Research Men

Researchful young scientists are best located in the universities, and hence the laboratory director will find it advantageous to maintain contact and friendly relations of reciprocity with the heads of the important research training schools.

In selecting research men, the laboratory director will be guided largely by the opinions of others respecting the fundamental knowledge and professional ability of the candidates.

Experience and observations of research directors have shown that industry is preferable to genius. It may never carry any one man as far as genius has advanced individuals, but patient study and intelligent industry will carry thousands into comfort, and even into celebrity, with certainty; whereas genius often refuses to be managed.

Coördination of Research Effort

The predominant feature of all scientific research is the extended use of recorded experience, which confers the power to predict the results of effort. Thus, the ceramist proceeds with assurance to determine the suitability of a new material in making refractories, because he possesses through bibliochretic study a knowledge concerning similar substances, requirements, and methods of test, by means of which he can plan his research with reasonable certainty of definite conclusion. The collection of recorded experience on any subject involves comparison and critical analysis: it requires sound fundamental knowledge of the branch of science involved and of the systematic use of its literature (bibliochresis).

In order to progress in research, workers in pure and applied science should keep in line with psychological laws. The apprehension of a fact by the mind requires the exercise of the power of observation, and all research observations must be of a special character, minute, accurate, and selective. Observation means to see with attention, and as soon as concentration takes place a process of analysis begins, and the scientific investigator passes to classification and generalization. The student of science, and particularly the graduate student who is being trained in research method, should therefore be taught to distinguish between the possession of information and the power or habit of thought. Thinking has no substitute.

Evaluating Research Ideas

By F. O. CLEMENTS,[8] DAYTON, OHIO

JULIUS BARNES makes the statement that "During the last two decades, science and invention have aided the progress of industry as in no preceding similar period." He gives the following interesting comparisons:

1900 to 1920—Population, increase of 40 per cent
Food Products, increase of 58 per cent
Mine Products, increase of 128 per cent
Factory Products, increase of 95 per cent.

He further states that "There is not only the normal increase of an enlarging population and the normal increase which follows

[5] A company looking for a laboratory director cannot do better than ask for the suggestive aid of the Division of Engineering and Industrial Research of the National Research Council. If a chemist is desired for the directorship, it is advisable to request the additional assistance of the American Chemical Society. Mellon Institute also welcomes such an opportunity to serve industry.

[6] This presentment is based on the industrial management principles of F. W. Taylor (Principles of Scientific Management) and of A. H. Church and L. P. Alford (*Am. Machinist*, 1912, p. 857).

[7] On such elements, see the conclusions of the special committee on administration of The American Society of Mechanical Engineers (Trans. A.S.M.E., 1912, p. 1131).

[8] Technical Director, Research Division, General Motors Corporation.

a resumption of the constantly advancing standard of human possessions, which has been the feature of our national growth, but there is besides the acceleration of the standard of human possessions by the very enlargement of human earning power, which science and directing genius have made unmistakable effective."

Mr. C. F. Kettering likes to vision this advance somewhat in this fashion: "Egypt, Rome, and Greece reached the highest stage of their development when they had the largest number of slaves, which increased the productive capacity of their civilizations. Our own civilization has kept growing, despite the abolition of slavery, because of the development of mechanical power. Every man, woman, and child in the United States has at his command six horsepower, or the equivalent in work of one hundred and fifty slaves. We do not recognize these slaves. Some bring water into the house, others bring light, some carry messages, and all sorts of slaves are available to relieve the individual of physical labor and discomfort."

Twenty-five years ago there were comparatively few efforts at systematized research in the entire country. Research, as we know it today, was an untried experiment. Developments garnered from every-day necessities and simple observations will not answer today. The every-day world has become quite technical and complex, so much so that we cannot hope to maintain our position without the assistance that science can render.

Research Defined

Research, which means "To search and examine with continued care; to seek diligently; to search again; to examine anew," is really only organized, scientific study to insure the purposeful seeking of new knowledge. Research has been designated by innumerable names: "The life blood of progress;" "The creative force of industry;" "The mother of industry;" "The future of industry;" "The welfare of the race." Pasteur says, "Science is the soul and the prosperity of nations, and the living source of all progress." If these flattering terms are deserved, it involves great responsibility on research personnel, relative to the selection of worth-while problems. The ancestor of every human action is a thought. Our only assets in research are ideas, and the thought world in which we labor is infinite.

The most difficult of all questions in a research laboratory is the selection of the task and the enlisting of the proper coöperative effort so that the whole organization may act effectively until the problem is solved.

Groups of trained and well-educated men are brought together, properly housed, and furnished with adequate equipment, and are set to work on the major problems of an industry. Men of initiative are sought, and they work tirelessly at a definite place on a single problem until success comes. An organization of trained minds is vastly superior to the old system of scattered effort, where all investigation was done by unattached individuals. That was the day of the inventor, and his products were rarely useful commercially.

Ultimate Object of Research

The ultimate object of all research is twofold: to increase the earning capacity of the corporation or individual, and to fulfil the obligation of all really important business organizations—to contribute something constructive to society. There can be no excuse for unsound ideas. Engineering really came into being when men substituted exact methods of measurements for guesses and opinions, and it is on the foundation of exact facts that big industry must build to survive. Engineering research applies ways, means, and methods that science has developed to observe, experiment, measure, and verify facts. To count is a modern practice: the ancient method was to guess; and, strange to say, when numbers are guessed they are usually magnified.

Research boiled down to its essence is nothing but self-education. Before we can direct our thoughts along profitable channels we must study a problem intensively and know its fundamentals. Every bit of help available is focused on the problem at hand. The technical library presents abstracts of articles appearing in the literature, representing the best thought of the world's workers on the particular subject. There are untold millions of work hours stored up in our libraries. Sometimes it would seem that we have enough available data, and fail to utilize it to its full advantage.

Scientific research must be untrammeled and free from restraint. Each section head is allowed a certain appropriation to help him determine the value of an idea. Some prefer to make the preliminary calculations on paper; others reduce them to small wood or metal models. If the idea develops well, and seems sound, a request is made for a project appropriation. Prior to a request for approval, we try to evaluate the usefulness of the idea ourselves. Somewhat after this procedure, which applies equally to pure- and applied-science problems—for there is only one objective: the search for truth and knowledge. The thought first; its proving and application last.

What a Research Project Should Include

All research work with us reflects itself on the products which our corporation makes and sells. A research project, to be worthy of a place on our program, should do one or more of the following things:

1. Reduce costs of production
2. Reduce operating costs to the user
3. Increase the utility of the product
4. Increase its sales appeal
5. Produce new business
6. Determine technical information contributory to some other project.

The relative value of the proposed project is based largely upon the quantitative value of the analysis itself. For instance, our Rubber Research applied to fan belts resulted in a long-lived product at a reduced cost, which benefited the entire industry. This project, following this economic survey, was allocated in value somewhat on the following basis:

Reduction in cost of production, 10 per cent
Reduction in operating costs to our customers, 30 per cent
Increased utility of the product, 50 per cent
Technical information applicable to related rubber projects, 10 per cent.

It actually worked out with a much larger saving in cost of production, and influenced engine design in an extremely favorable way.

Pure-science workers rarely know what end they will achieve. Without fundamental studies and their cumulative results, nothing can be intelligently applied. Finding the use for an accumulated fact is also research. It includes the study of the commercial requirements and the problems pertaining to practical production. Results, despite great care, are sometimes intangible, but after all, the general product of research is information. Like most valuable things, information founded on facts and truth comes in small packages and usually represents a maximum amount of hard mental labor. A worth-while research program must carry a goodly percentage of pure-science research; for it is the seed corn containing the program that lies just ahead; the magic power that is extending the boundaries of every field of human endeavor. It affects our mental aspect, our entire social structure, and even decides the economic fate of nations.

Coöperation between Industry and University

By GEORGE D. McLAUGHLIN,[1] CINCINNATI, OHIO

I AM INTERESTED in showing that, whether we like it or not, the problem of the relation between industry and university, is with us, and cries for answer. There is at least one answer to this question, which I will attempt to describe.

The life of every university depends upon its receiving, each year, the funds necessary for its conduct. These funds, whether received by the university as tuitions, endowments, or taxes, represent a portion of the wealth produced over and above the actual living costs of the population of the community supporting the institution. In a previous age these moneys came largely from the fruit of the soil; today they result mainly from the dividends paid

[1] Director, Research Laboratory of the Tanners' Council of America, University of Cincinnati.

directly or indirectly by industry. When industry ceases to pay dividends, the university must close.

Growth of Industry Dependent Directly on Quality of the University Scientist

The life, the growth of industry depends directly upon the quality of the university scientist. Few industrialists understand this. Captains of industry and finance, proud in the realization of their power and remembering the power plants, the fleets of ships, or the compound locomotives which move at their command, vainly imagine that all this is their creation; the fruit of their dynamic, restless toil. Not long ago I heard an industrial group describe, in terms of admiration, the very large sum paid a comparatively young man for a radio business which he had "built up." I asked in what proportion the credit should be divided between this man and Clerk-Maxwell. They knew of no one in the radio business named Clerk-Maxwell. An industrial captain recently expressed his profound disapproval of the graduate school of a well-known university, maintaining that its cloistered walls unfitted students for grasping the important, practical problems of business. He was evidently ignorant of the fact that his own industry was born in such rooms; nor did he realize that the next and logical development of this industry is now awaiting the results of the work—not of his efficiency experts or business prognosticators—but of research scientists, whose very names he probably does not know.

I do not fear the commercialization of our universities. The strength and value of such institutions depends solely upon the character and ability of the men composing them. Strong men will not be commercialized. Nor need we be apprehensive lest the pursuit of knowledge for its own sake shall perish, or the love of scholarly pursuits, if we will only remind ourselves that human nature changes slowly, if at all. Scholars will continue in the future, as in the past, to represent a quite small percentage of the student rank and file, but they will continue in the future to appear and to do their work because they love it.

If scholars and industrialists will realize that their diverging tastes are equally legitimate (since even scholars must be fed, clothed, and transported), that each is entitled to pursue the work at hand, and that, after all, they have something in common, both will be benefited. This common point of contact has, during the past four years, been partially achieved by the Tanners' Council of America and the University of Cincinnati.

The Tanners' Council is composed of the leather manufacturers of the United States. Tanning is a basic industry, since leather is needed for shoes, harness, belting, upholstery, and many other uses. It is one of the largest American industries from the standpoint of capital investment. The tanning of leather was one of the first steps of civilized man. Throughout many ages and into the present day, tanning was an empirical practice, the "secrets" of which were handed down from father to son. This was the result of an abundant supply of cheap raw material and mild competition. Under the stimulus of diminishing supplies of domestic raw materials and ever-increasing competition, a new viewpoint was born. Progressive members of the industry realized that if they were to maintain or advance their position, the scientific laws underlying the materials and processes of their industry must be written.

Coöperation of University and Industry in Tanning Research

The processes of tanning involve the conversion of the animal tissue skin into the useful, imputrescible article called leather by means of tanning agents, both organic and inorganic. The science of tanning involves nearly every important branch of chemistry, just as do the problems of the modern medical investigator of other animal tissues; it involves also the action of bacteria and the histological picturing of structural changes. Such far-flung and fundamental studies called for a variety of scientific talent, for physical equipment, and for time.

The Council wisely turned to a university. A gentlemen's agreement with the University of Cincinnati was reached which has subsequently become the basis of a formal contract. The agreement is brief and simple and provides that: (1) No research work shall be undertaken which is not of a strictly fundamental character; which means, of course, that no "hack" work or special problems of particular contributing corporations will be considered; (2) the Council will furnish the funds needed for the prosecution of the work; and (3) the results of all research will be freely published in reputable scientific journals.

From the viewpoint of the average industrialist the contract is unbusiness-like; from the standpoints of the really progressive manufacturer and the university it is the only adequate method of meeting the problem, of insuring work of fundamental quality, and of attracting to it men of university caliber.

The agreement has "worked" in practice. During the early stages of the research there were, as would be expected, expressions of discontent from the less progressive, unimaginative members whose understanding of fundamental conceptions was necessarily vague and who expected the tree to grow to maturity and yield a golden crop within a month after planting. Another well-meaning group felt the urge of offering suggestions of "problems" demanding immediate attention, without, of course, any conception of whether their suggestions had a scientific basis. When such misdirected, though well-intentioned, efforts possess sufficient pressure, the scientist (whom the industrial group looks to for "results") often loses heart, his enthusiasm is dampened, and, realizing the futility of the situation, he simply resigns. Or, if he lacks sturdiness, he is overawed by the powers before him and begins a necessarily fatal compromise; he seeks to pacify one group by investigating some probably wholly unessential problem they suggest. Scarcely is this done when another group, or a particular corporation, not to be outdone, advances with a suggestion; the precedent has been established and he must meet their demand. In a comparatively short period the scientist's time and energy are divided between routine analytical or testing work and a feverish effort to placate the ever-growing disappointment of the industrial group which had been led to expect large increases in their dividends. Thus the undertaking which started with the martial strains of a brass band ends with the weak notes of a harmonica. The net result is that a substantial sum of money has been wasted and nothing gained but disillusionment.

The foregoing conditions were realized by a committee of progressive members of the Council, who took the steps necessary to safeguard the research laboratory. This committee functions as a buffer between the laboratory and the industry. Expressions of complaint or suggestions of problems are sent to them and are given consideration and reply. If the matter is of importance it is submitted to the laboratory, for the director's consideration. Thus, for four years, the laboratory at the University of Cincinnati has been enabled to concentrate upon essentials. It has formulated certain laws. For example, the curing of animal skin following slaughter is of great importance: the skin is cured so that it may be transported from abattoir to tannery without bacterial decomposition. The laws underlying this process were established and today, instead of a heterogeneous mass of unrelated observations and data, there exist simple, clear-cut laws which govern the curing of any skin, be it rabbit, ox, or elephant, and whether it is slaughtered in Chicago, Hong Kong, or Capetown. Again, a very important tannery process is termed "soaking," by which the skin is prepared for the unhairing treatment. The laws governing this process have been evolved. They have been applied by a dozen large corporations to meet their special conditions. Each of these corporations has been enabled to secure more and better leather from a unit of raw material, and at no additional manufacturing cost. In other words, the work has produced wealth far in excess of its cost.

I have thus outlined one answer to the problem of the relation of university and industry. Wealth has been produced for industry, and the university has been supplied the funds and facilities for the prosecution of scientific research. Each group has gained, neither has lost.

It may be correctly argued that the motive guiding the expenditures of the Council lies mainly in the hope of greater profits rather than in the furtherance of knowledge for its own sake. Equally true, however, is the fact that these increased profits are the surest means of interesting industry in the general activities and aims of a university. If industry shall ultimately assume its proper share in supporting general education and research—whether in the arts, the sciences or the humanities—it will be because the university has shown itself to be the ultimate source of increased dividends.

Book Reviews and Library Notes

The Library is a coöperative activity of the A.S.C.E., the A.I.M.E., the A.S.M.E. and the A.I.E.E. It is administered by the United Engineering Society as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West 39th St., New York, N. Y. In order to place its resources at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies of translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

Principles of Industrial Organization

PRINCIPLES OF INDUSTRIAL ORGANIZATION. Third edition, rewritten and rearranged. By Dexter S. Kimball. McGraw-Hill Book Co., New York, 1925. Cloth, 6 × 9 in., 436 pp., illus., $4.

IT IS a pleasant task to review the enlarged third edition of Dean Kimball's Principles of Industrial Organization. This book is comprehensive, many-sided, and of remarkable judgment and balance. It is no torpid assemblage of cost records and organization charts—though both appear. It gives no rigid, mechanistic treatment of management problems—though based throughout on qualitative and quantitative study of human performance. The book is one that covers the whole range of the industrial problem, and takes particular cognizance of its social and human relations. Almost every paragraph has implications which point well beyond the immediate subject-matter, toward questions of the largest importance. Reading it is a stimulating exercise.

The book begins with a review of industrial progress, and a critical analysis of its present state. No one has more clearly seen and stated the principles of the Industrial Revolution. Its early social effects are described and its history brought up to date. Next follows a review of modern industrial tendencies and forms of ownership. Subsequent chapters deal with the manufacturing plant itself, with forms of organization, and with such details of management as production control, time study, wage systems, purchasing, stock keeping, inspection, cost finding, accountancy, employee service, etc., etc.

The criticisms that occur to the writer are few. One of them relates to inspection. It is a mistake to relieve the workman, or his foreman, of any degree of responsibility for the quality of his output. Where the timing of the machine is such that the operator can measure or otherwise examine his work, he himself should set aside the spoiled pieces, and the foreman should be held at fault if the man is not trained to do so. The modern tendency to put the full burden on the inspector is an economic error, and a moral one to boot. Of course, this criticism would not apply to complicated technical processes such as might be met with in chemical reactions, but the principle holds wherever it can be applied.

No mention is made of one of the most modern and successful methods of wage payment—that by simple task. In well-managed automobile plants the tendency is to determine the efficient production from a given machine, provide carefully for all the conditions necessary to attain that production, and then pay the operator high wages for reaching it. If he does not reach it, his wages are not cut—he is replaced. This is a somewhat summary and inhuman method, but in actual practice it does not always result in as tense, frenzied activity as is met with on premium or piece work where the basic conditions have not been carefully provided for by the management.

Payment by simple task is usually dependent on Continuous production—and continuous production is one of the outstanding features of present-day development which does not seem to be adequately treated. When the output of a given product has reached such a volume that every operation required can be performed continuously, without shifting men and machines from one operation to another, every element of management is thereby immediately simplified. The difference is as great as that between the complexity of despatching trains of all classes going in both directions on a trunk-line railroad, and the simplicity of pumping oil through the pipe line that runs alongside. The simplification and resulting efficiency enter into every item of cost and every phase of management.

Continuous production is, of course, dependent on a simplified range of product, made preferably of standardized parts. It is a pleasure to note that Dean Kimball gives a most satisfactory treatment of the subjects of standardization and simplified practice, analyzing the results in the industrial field and in their social influence as well. There need be no fear that standardization will permanently extend beyond its natural sphere. It should release an increasingly larger volume of craftsmanship and taste for employment in the fields of artistic design and production, where uniformity and standardization have no place.

Particularly satisfying is the résumé in the last chapter. Here it is again clearly stated that management is not 100 per cent science. There always remains an *art* of management to be reckoned with. As Dean Kimball says, "Two men may be given the same equipment of machines and knowledge; one will be successful and the other will fail. The basic facts or laws of any field are *impersonal*, but their execution or administration almost always involves personal qualifications on which success or failure may, and usually does, depend." This is particularly good for students to know, and it is the lack of such knowledge that is the greatest handicap to them in adjusting their academic training to the requirements of practical life.

Our industrial organization is indeed a living organism, made up of many individual cells, each with its own specialized characteristics. These characteristics may be, must be, studied and cataloged, and the resulting information scientifically applied. Yet the behavior of the lowest animal cell, the amoeba, is predictable only in a general way. One never knows just what shape it will writhe into when it is pricked. Men are far less simple and far more sensitive than amoebas.

RALPH E. FLANDERS.[1]

Books Received in the Library

DAMPFKESSELWESEN IN DEN VEREINIGTEN STAATEN VON AMERIKA. By Friedrich Münzinger. V. D. I. Verlag, Berlin, 1925. Paper, 8 × 12 in., 46 pp., illus., diagrams, 4.50 r.m. ($1.08).

A report, by a German expert, on steam-power-plant methods in America, as observed during a recent tour of investigation. Dr. Münziger visited the larger cities east of the Mississippi river and examined the best examples of current practice in steam generation. The report is an excellent survey of conditions and is profusely illustrated with charts and photographs.

ELEMENTS OF INTERNAL-COMBUSTION ENGINEERING. By Telford Petrie. Longmans, Green & Co., London and New York, 1925. Cloth, 6 × 9 in., 236 pp., diagrams, $3.75.

The various types of gas and oil engines, their cycles of operation, ideal cycles and their functions, the thermodynamics of the gas engine and the other theoretical considerations of these engines are discussed. The work is confined to theory and does not discuss practical details of design.

[1] Mgr., Jones & Lamson Machine Co., Springfield, Vt. Mem. A.S.M.E.

FREIGHT TERMINALS AND TRAINS. By John A. Droege. Second edition. McGraw-Hill Book Co. New York, 1925. Cloth, 6 × 9 in., 567 pp., illus., diagrams, $6.

A treatise on freight transportation in all its ramifications, written from the viewpoint of the engineers who plan and build the various plants that form the organization, and the officers who operate them. The present edition has been enlarged to include a chapter on electrical operation and another on the integration of freight transportation. Descriptions of new developments in facilities have been inserted where necessary to bring the work up to date.

HEALTH MAINTENANCE IN INDUSTRY. By J. D. Hackett. A. W. Shaw Co., Chicago and New York, 1925. Fabrikoid, 6 × 9 in., 488 pp., diagrams, tables, $6.

Increasing appreciation of the relation between the health of workmen and their efficiency has led to the establishment of medical departments in many plants. This book gives an account of the organization of such a department and of the ways in which it may aid production. The subject is treated simply, from the point of view of the plant manager, who is responsible for the direction of the activities of the department, but has no medical training.

HEPHAESTUS; or, The Soul of the Machine. By E. E. Fournier D'Albe. E. P. Dutton & Co., New York, 1925. Cloth, 5 × 7 in., 76 pp., $1.

An interesting, original study of the relations between man and his machines. How the age of machinery has come about and what influence machinery will eventually have on society is explained in striking fashion in this little book.

HOLZDAUBENROHRE. By Herbert Rabovsky. V. D. I. Verlag, Berlin, 1926. Paper, 6 × 8 in., 68 pp., illus., tables, graphs, 8 r.m.

This monograph is intended to call the attention of European engineers to the possibilities of wood-stave pipe, an article little known as yet to them. The pamphlet summarizes home and foreign practice, describes pipe lines of importance and discusses theoretical considerations. A graphic chart for determining sizes is given and there is a statistical table of installations in central Europe.

INDUSTRIAL FURNACES, vol. 2. By W. Trinks. John Wiley & Sons, New York, 1925. Cloth, 6 × 9 in., 405 pp., illus., diagrams, tables, $5.50.

While the first volume of this important work was largely theoretical and of particular interest to the designer, this volume is primarily devoted to practice and makes its appeal to those who select, install, and operate furnace equipment. The author discusses fuels, combustion devices, temperature control, atmosphere control, and labor-saving devices, compares various fuels and types of furnaces, and offers advice on their selection. Electric furnaces are included in the discussion.

JAHRBUCH DER BRENNKRAFTTECHNISCHEN GESELLSCHAFT, E. V., 1924. Vol. 5. Wilhelm Knapp, Halle (Saale), 1925. Paper, 8 × 11 in., 112 pp., illus., diagrams, 7.80 gm.

The fifth yearbook of the Society includes a report of the proceedings at the annual meeting of December, 1924, and several of the papers read at that time. These include addresses on Internal-Combustion Engines, Especially Diesel Locomotives for Railways, by H. Nordmann; Ignition Phenomena in Gas Engines, by J. Tausz; Large Diesel Engines for Ships, by R. Dreves; Raising the Power of Gas Engines through Precompression by Blowers, and the Use of Exhaust Gases in Turbines to Drive These Blowers, by W. G. Noack; The Principles of High-Speed Semi-Diesel Engines, by Dr. Büchner; and On the Numerical Expression of the Idea of the Quality Calorie, by W. Ostwald.

DIE LEISTUNG DES DREHSTROMOFENS. By J. Wotschke. Julius Springer, Berlin, 1925. Paper, 6 × 9 in., 70 pp., diagrams, tables, 5.10 g.m.

Books on the electric furnace are not numerous, and in those that exist less attention is paid to the needs of the electrical engineer than of the chemist and metallurgist. In this book the author attempts to meet electrical requirements by a discussion of the electrical theory and of the electrical factors that make for the greatest efficiency. He calls attention to opportunities for research in this field.

LIFE OF ELBERT H. GARY; the Story of Steel. By Ida M. Tarbell. D. Appleton & Co., New York, 1925. Cloth, 6 × 9 in., 361 pp., illus. portraits, $3.50.

Miss Tarbell's biography of the head of the United States Steel Corporation is not only an interesting life of the great industrial leader, but also a history of an important period in the development of a great basic industry. Beginning with the first combines in the early nineties, the changing consolidations, the formation of the Steel Corporation and the development of its policies toward labor and the public are carefully traced, down to the present.

MAKING, SHAPING AND TREATING OF STEEL. Fourth edition. By J. M. Camp and C. B. Francis. Carnegie Steel Co., Pittsburgh, Pa., 1925. Fabrikoid, 5 × 8 in., 1142 pp., illus., diagrams, tables, $7.50.

This book is intended primarily for use as a textbook in the schools conducted by constituent companies of the United States Steel Corporation for employees without a technical education. It is also admirably adapted to the needs of every one wishing an accurate account of standard practice in the American steel and iron industry. Beginning with a survey of those principles of physics and chemistry which are useful to the metallurgist, the authors take up refractories, iron ores, fuels, fluxes, describing their varieties, properties and uses. The manufacture of pig iron, wrought iron, and steel is then discussed. Section two is devoted to the shaping of steel by rolling and forging. Section three treats of the constitution, heat treatment, and composition of steel. Section four describes the manufacture of wire, sheets, pipe, and tubes. No other book approaches this in its fullness of detail on current practice in American iron and steel works. It is a complete account of the industry, from the ore to the semi-finished product, prepared by men in intimate contact with current practice.

MECHANICAL INVESTIGATIONS OF LEONARDO DA VINCI. By Ivor B. Hart. Open Court Publishing Co., Chicago, Ill., 1925. Cloth, 6 × 9 in., 240 pp., illus., facsimiles, portraits, $4.

The author's primary purpose was to make a detailed study of the nature and value of Leonardo's contribution to the study of aeronautics, but as the study of flight is linked with that of mechanics, the whole field of his work in mechanics has been surveyed. After an introductory chapter on the characteristics of Leonardo's manuscripts, there is a discussion of the state of mechanical science in the fifteenth century, of the scientific influences that bore upon Leonardo, and of the sources of information available to him. This is followed by an account of his work in mechanics and as a pioneer of aviation. The book concludes with a complete translation of his Codex on the Flight of Birds and Other Matters from the manuscript in the Library of Turin.

MECHANISM OF THE CAR. By Arthur W. Judge. Chapman & Hall, London, 1925. (Motor manuals, vol. 3.) Cloth, 5 × 8 in., 175 pp., illus., 4s.

A non-technical exposition of the basic principles, illustrated by examples from current automobile practice. Covers the chassis, transmission, gears, etc. While adapted to use by owners and mechanics, it also will interest the engineer.

METALLURGIE. By Aug. Geitz. Walter de Gruyter & Co., Berlin and Leipzig, 1925. 2 vols. Cloth, 4 × 6 in., illus., diagrams, 1.25 gm. each.

A convenient survey of the metallurgy of the metals, excluding iron, intended for those who wish access to the important facts but lack time for more extensive accounts. The methods of extraction, history, occurrence, properties, uses, and statistics of each metal are given. Rare metals and those without technical importance are included.

NIAGARA IN POLITICS; a Critical Account of the Ontario Hydro-Electric Commission. By James Mavor. E. P. Dutton & Co., New York, 1925. Cloth, 5 × 8 in., 255 pp., $2.

Professor Mavor's work is an indictment of the Hydro-Electric Power Commission of Ontario, which he condemns on grounds of both public policy and of economic advantage.

DIE OLFEUERUNG. By Bruno Schulz. Wilhelm Knapp, Halle (Saale), 1925. Paper, 7 × 10 in., 201 pp., illus., diagrams, tables, 9.80 mk.

The author, formerly in administrative charge of oil firing in the German Navy Department, has compiled an account of the

development of the practice in the navies and merchant services of America, England, Germany and other countries. The burners, air-regulating apparatus and accessory equipment are described, as well as the special arrangements required for using oil fuel. Methods of testing are included, with a discussion of economic and technical problems.

Oil Engine Power Plant Handbook. By Staff of *Oil Engine Power*. *Oil Engine Power*, New York, 1925. Fabrikoid, 8 × 11 in., 192 pp., illus., diagrams $3.

The work is a combination of catalog information on the products of various manufacturers of oil engines and accessories, with a series of articles by various engineers. These articles treat of such matters as lubrication, operation and maintenance, valve setting, installation, and similar topics, and are written from a practical viewpoint.

Optische Messungen. By Fritz Löwe. Theodor Steinkopff, Dresden and Leipzig, 1925. (Fortschritte der Chem. technologie in einzeldarstellungen, vol. 6.) Paper, 6 × 9 in., 166 pp., illus., 6 gold marks.

The series of reports to which this example belongs, is intended primarily to assist German chemists by providing reviews of the advances made since the commencement of the World War. The present monograph on optical measuring will appeal to analysts, physicians, and chemists in the metallurgical, oil, and sugar industries. Its three chapters deal respectively with spectroscopy, refractometry, and interferometer methods of measuring. Novel designs of apparatus, new applications, and new methods are described, with references to the original publications.

Oscillographs. By J. T. Irwin. Issac Pitman & Sons, New York, 1925. Cloth, 5 × 7 in., 164 pp., illus., diagrams, $2.25.

After a chapter on the fundamental principles involved, the author describes the various types of oscillographs and the methods of damping. Much space is given to the cathode-ray oscillograph. The book is apparently the first in English devoted to the subject and is, the author remarks, to a great extent original.

Patents; Law and Practice. Third edition. 1924. 56 pp.
Trade-Marks, Trade Names, Unfair Competition. Fourth edition, 1925. Paper, 6 × 9 in., 48 pp., Richards & Geier, 277 Broadway, New York. Gratis.

These pamphlets provide a convenient summary of the patent and trade-mark laws of the principal countries of the world. They are intended to give laymen the more important facts, as a guide in meeting the problems that arise most frequently.

Petroleum Register. Mid-year edition, 1925. *Oil Trade Journal*, New York, 1925. Cloth, 9 × 12 in., 581 pp., maps, $10.

Buyers and sellers of petroleum and its products will find in this book information on producers, refiners, compounders, marketers, jobbers, and others associated with the oil industry. The data include the location, officers, capitalization, and equipment of the companies. The book also contains much statistical information, lists of oil associations, and outline maps of the oil fields of the world.

Practical Marine Diesel Engineering. By Louis R. Ford. Simmons-Boardman Pub. Co., New York, 1925. Fabrikoid, 6 × 9 in., 512 pp., illus., diagrams, $7.50.

Discusses the theoretical principles of the Diesel engine, the construction of its various stationary and moving parts, and its accessories. Descriptions of typical commercial engines of various types are given, and a large part of the book is devoted to the operation of Diesel engines and the derangements likely to occur. The book is intended for the use of practical enginemen, especially for the marine steam engineers who wish to operate these engines.

Proceedings of the First International Congress for Applied Mechanics. Delft, 1924. Edited by C. B. Biezeno and J. M. Burgers. J. Waltman, Jr., Delft, 1925. Boards, 8 × 11 in., 460 pp., illus., diagrams, tables, 18 fl.

The Delft congress on applied mechanics was called by a committee of Dutch scientific workers, to promote a closer contact of those interested in the science of mechanics. A successful conference, attended by over two hundred persons, was held, and a permanent organization was formed.

Fifty-one papers were presented and discussed and are published in the present volume. The papers divide into three general groups: rational mechanics, the theory of elasticity, and hydrodynamics and aerodynamics. Among the topics treated are graphical and numerical methods for solving differential equations; experimental methods for solving stress problems; the theory of rupture; the physical aspects of non-elastic deformations; motions in rotating fluids; the stability of fluid motions; wave motion; the motion of a fluid in the boundary layer along the surface of solids; and the dynamics of the atmosphere. Thirty-two of the papers are in German, fourteen in English, and five in French.

Prometheus; or, Biology and the Advancement of Man. By H. S. Jennings. E. P. Dutton & Co., New York, 1925. (Today and tomorrow series.) Cloth, 4 × 6 in., 86 pp., $1.

This interesting little work is designed as a statement of the present situation of scientific knowledge in genetics. The questions that Professor Jennings discusses are the relations of heredity and environment and the extent to which they are responsibile for the advancement of man. This concise review of the questions is intended for the reader interested in any one of a number of practical questions.

Proteus, or the Future of Intelligence. By Vernon Lee. E. P. Dutton & Co., New York, 1925. (Today and tomorrow series.) Cloth, 4 × 6 in., 63 pp., $1.

In this very interesting little volume the author discusses intelligence: what it is, when it originated, and how it influences us in the realms of art, religion, morals, and economics, and in our personal lives and outlooks.

Smoke, A Study of Town Air. By Julius B. Cohen and Arthur G. Ruston. New enlarged edition. Edward Arnold & Co., London; Longmans, Green & Co., New York, 1925. Cloth, 6 × 9 in., 108 pp., illus., tables, $3.20.

The authors of this book have not entered into the subject of the cause of smoke and the cure for it but have confined themselves to collecting accurate data on the imperfect combustion of coal and presenting an accurate picture of the consequences. The book discusses the composition of soot, the amount emitted from chimneys and its effect upon vegetation and light; the effects of flue gases on structures and vegetation; town fog; the dispersal of soot; and the plant as an index of smoke pollution. The facts presented should be helpful to every one interested in smoke abatement.

Staub-Explosionen. By Paul Beyersdorfer. Theodor Steinkopff, Dresden and Leipzig, 1925. Paper, 6 × 9 in., 125 pp., illus., tables, 5.50 mk.

A summary of our knowledge of dust explosions. Discusses their character, the dangerous properties of dust, effects of heat and static electricity, the action of explosions and methods of prevention. The book is intended to present the situation in a form convenient for consultation by those engaged in dusty industries.

Tagung des Allgemeinen Verbandes der Deutschen Dampfkessel-Uberwachungs-Vereine. April, 1925, Karlsruhe. V. D. I. Verlag, Berlin, 1925. Paper, 9 × 12 in., 132 pp., illus., diagrams, plates, 16 gm.

The proceedings contain reports and discussions upon a number of important matters relating to boiler operation. Among these are the tension in heavy boiler plates; the influence of temperature, shape of test piece and speed of testing upon notched-bar tests; American rules for water-purifier operation; accessories for high-pressure boilers; autogenous and electric welding for boiler parts; the high-pressure boiler. Statistics of boilers are appended.

Technische Wirtschaftslehre. By Prof. Theodor Janssen. Wilhelm Engelmann, Leipzig, 1925. Cloth, 7 1/4 × 10 3/4 in., 379 pp., 3 illus.

General book on engineering economics, presenting briefly the general principles of economics and then more comprehensively questions of economic accounting. A chapter is devoted to distribution of goods, including banking credit, security markets, and tariff questions, and another chapter to the discussion of various economic systems, such as capitalism, socialism, etc.

THE ENGINEERING INDEX

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THE ENGINEERING INDEX presents each month, in conveniently classified form, items descriptive of the articles appearing in the current issues of the world's engineering and scientific press of particular interest to mechanical engineers. At the end of the year the monthly installments are combined along with items dealing with civil, electrical, mining and other branches of engineering, and published in book form, this annual volume having regularly appeared since 1906. In the preparation of the Index by the engineering staff of The American Society of Mechanical Engineers some 1200 technical publications received by the Engineering Societies Library (New York) are regularly reviewed, thus bringing the great resources of that library to the entire engineering profession.

Photoprint copies (white printing on a black background) of any of the articles listed in the Index may be obtained at a price of 25 cents a page. When ordering photoprints identify the article by quoting from the Index item: (1) Title of article; (2) Name of periodical in which it appeared; (3) Volume, number, and date of publication of periodical; (4) Page numbers. A remittance of 25 cents a page should accompany the order. Orders should be sent to the Engineering Societies Library, 29 West 39th Street, New York.

AERONAUTICS

German Show, Munich. Aeronautical Exhibits at the Munich Transportation Show. Zeit. für Flugtechnik u. Motorluftschiffahrt, vol. 16, no. 17-18, Sept. 9, 1925, pp. 329-398. Special number devoted entirely to aeronautical part of exhibition; it contains extensive description and illustrations of exhibits of various departments and work they represent, including aircraft design, aerial photography, aeronautical psychology, as well as descriptions of all the more important airplanes with details of construction; mention is made on p. 335 of steel-net dirigible of German Aircraft Co. which is fundamentally non-rigid, but steel net underneath exterior covering makes it possible to use very high pressure and to put in bulkheads and subdivided gas cells; another article (pp. 350-354) deals with psychological tests used to determine influence of altitude on mental faculties; it appears that up to 15,000 or 16,000 ft. there is no impairment; beyond that mental operations become undependable and faculties of observation dulled; oxygen breathing gives good compensation for altitude.

AIR COMPRESSORS

Centrifugal, Testing. The Heat Balance Method of Testing Centrifugal Compressors, M. G. Robinson. Am. Soc. Mech. Engrs.—advance paper, for mtg. Nov. 30-Dec. 4, 1925, 23 pp., 11 figs. Describes method which is simple and direct, in which principle is used that balance exists between mechanical energy supplied by rotation of shaft and heat-energy increase in air which is being compressed, heat-energy increase in cooling water used, and heat lost from casing, bearings, and packings; with proper testing apparatus and due precautions this heat energy may be accurately measured and hence power input established; very satisfactory results have been obtained by application of method.

Electrically driven. A New Type of Electrically-driven Air Compressor. Commonwealth Engr., vol. 13, no. 1, Aug. 1, 1925, pp. 17-18. Particulars of N-SE electrically driven compressors manufactured by Consolidated Pneumatic Tool Co., Fraserburgh, Scotland, made in capacities from 107 to 1196 cu. ft. of free air per minute piston displacement, which in horsepower rating is from 20 to 100; suitable for all classes of work where air pressure does not exceed 125 lb. per sq. in.

AIR PUMPS

Steam-Jet. New Developments in High Vacuum Apparatus, G. L. Lothny. Soc. Nav. Architects & Mar. Engrs.—advance paper, no. 1, for mtg. Nov. 12-13, 1925, 7 pp., 13 figs. on 11 supp. plates; also (abstract) in Mar. Eng. & Shipg. Age, vol. 30, no. 12, Dec. 1925, pp. 717-718, 3 figs. and (discussion) pp. 689-690. Records most important developments in design and performance of steam air ejectors made during last 6 years.

AIRPLANE ENGINES

Design. Designing Engines Into Airplanes, J. G. Vincent. Aviation, vol. 19, no. 22, Nov. 30, 1925, pp. 776-778, 3 figs. Air and water-cooled engines; types of water-cooled engines; geared or direct drive; advantages of geared drive; engines for pursuit types.

Evaporative Cooling. The Evaporative Cooling of Aircraft Engines, T. R. Cave-Browne-Cave. Automobile Engr., vol. 15, no. 209, Nov. 1925, pp. 422-424, 6 figs. Results of investigations, theories and conclusions. Paper read at joint mtg. of Roy. Aeronautical Soc. and Instn. Automobile Engrs.

Performance. Aviation Engine Performance, S. W. Sparrow. Franklin Inst.—Jl., vol. 200, no. 6, Dec. 1925, pp. 711-730, 12 figs. Discusses what performance may reasonably be expected of aviation engines.

Splines and Serrations. Splines and Serrations, H. T. Wright. Machy. (Lond.), vol. 27, no. 687, Nov. 26, 1925, pp. 259-262, 13 figs. Principles underlying design of splined connections and serrated shafts, with special reference to aircraft work.

Star Type. The Inertia Forces and Couples and Their Balancing of the Star Type Engine, K. Tanaka. Aeronautical Research Inst.—Report, Tôkyô Imper. Univ., No. 10, Mar. 1925, pp. 247-304, 7 figs. Investigation consists of three parts: radial engine, rotary engine, and comparisons with other types of engines.

Supercharging. Gear-Driven Plane Supercharger Passes Dayton Air Tests, D. Gregg. Automotive Industries, vol. 53, no. 22, Nov. 26, 1925, pp. 906-908, 5 figs. Air Service Eng. Division finds early failures due to crankshaft torsional vibration; use of larger impeller shaft and flexible coupling solved problem.

AIRPLANES

Aerodynamic Characteristics. Aerodynamic Characteristics of Aircraft with Reference to Their Use, M. Panetti. Nat. Advisory Committee for Aeronautics—Tech. Memorandums, no. 339, Nov. 1925, 12 pp. Definition of characteristics of airplanes, gradually becoming more precise, minutely describes and almost identifies type, by imposing choice of ever more perfect shape for satisfying requirement; necessity of positive knowledge of properties of wing profiles and of aerodynamic characteristics of wings and stabilizing planes, is pointed out. Translated from L'Ala d'Italia, Apr. 1925.

All-Metal. Advantages of the All-Metal Airplane, W. B. Stout. Automotive Mfr., vol. 67, no. 7, Oct. 1925, pp. 8-10 and 26. A consideration of airplane transport from a purely commercial viewpoint, and type of "ship" which has resulted; constructional details.

Bleriot. The New Four-Engined Bleriot Airliner. Aviation, vol. 19, no. 24, Dec. 14, 1925, pp. 844-845, 2 figs. Type 155 evolved from former designs along similar lines; carries 17 passengers besides pilot and navigator-mechanic and will be used on Paris-London line.

Flying Boats. See FLYING BOATS.

Fokker. Official Performance Test of Fokker PW-7 Equipped with Curtiss D-12 Low Compression Engine. Air Service Information Circular, vol. 6, no. 529, July 1, 1925, 7 pp., 6 figs. Summary of results; distribution of weights; description of airplane; pilot's observations.

Gloster. Two "Gloster" Machines. Flight, vol. 17, nos. 46 and 47, Nov. 12 and 19, 1925, pp. 743-746 and 763-767, 14 figs. Particulars of "Grouse II" and "Grebe II" machines turned out by Gloucestershire Aircraft Co.; "Grouse II:" length 20 ft., span 27 ft. 10 in., area main planes 208 sq. ft., Armstrong-Siddeley "Lynx" engine; "Grebe II:" length 19 ft. 4 in., top span 29 ft., bottom span 25 ft., main planes 254 sq. ft., Armstrong-Siddeley "Jaguar" engine.

Junkers. The Junkers Model T29 (Die Junkers-Flugzeugtype T29). Motorwagen, vol. 28, no. 24, Aug. 31, 1925, pp. 525-526, 2 figs. Details of a small 2-seater with Junkers patented double wings, for use as experimental school or sport machine; it is all-metal construction and has air-cooled Junkers engine.

Maintenance Costs. Airplane Maintenance Costs —How to Estimate Labor and Materials, A. Black. Automotive Industries, vol. 53, no. 24, Dec. 10, 1925, pp. 990-992, 3 figs. Depreciation, engine not included, is estimated as 25 per cent a year for machines in commercial service; U. S. Air Mail data studied.

Moth Light. The D. H. 60 "Moth" Aeroplane. Automobile Engr., vol. 15, no. 209, Nov. 1925, pp. 396-400, 14 figs. Light 2-seater fitted with 27-60-hp. Cirrus engine. From Jl. Roy. Soc. Arts.

Seaplanes. See SEAPLANES.

Spars. Report of Static Test of Aeromarine (Experimental) Duralumin Spar (Second Article), E. R. Weaver. Air Service Information Circular, vol. 6, no. 524, July 1, 1925, 5 pp., 5 figs. Test to determine structural strength of this spar relative to its weight in pounds.

Statics. Stage of Development and Problems in Modern Airplane Statics (Entwicklungsstand und Probleme der modernen Flugzeugstatik), K. Rühl. Bauingenieur, vol. 6, no. 25, Sept. 25, 1925, pp. 58-75, 6 figs. Discusses importance of statics and gives numerical examples; examines static structure of airplanes; discusses principal post-war tendencies, influence of airplane statics on general building statics.

Vickers Airliner. The Vickers "Vanguard" Airliner. Aviation, vol. 19, no. 26, Dec. 28, 1925, pp. 912 and 914, 2 figs. One of latest European airliners carrying 22 passengers; equipped with Rolls-Royce "Condors," rated at 650 hp. each.

Wings. A Method for the Direct Determination of Wing-Section Drag, A. Betz. Nat. Advisory Committee for Aeronautics—Tech. Memorandums, no. 337, Nov. 1925, 8 pp., 3 figs. on supp. plate. Explains theoretical principles on which method developed by Ackeret for calculating wing-section drag directly from energy loss of air is based. Translated from Zeit. für Flugtechnik u. Motorluftschiffahrt.

Pressure Distribution on Joukowsky Wings, O. Blumenthal, and Graphic Construction of Joukowski Wings, E. Trefftz. Nat. Advisory Committee for Aeronautics—Tech. Memorandums, no. 336, Oct. 1925, 20 pp., 6 figs. on supp. plates. Qualitative discussion of pressure distribution; first part deals with mathematical and hydrodynamic aspects, and second part takes up discussion from practical standpoint. Translated from Zeit. für Flugtechnik u. Motorluftschiffahrt, May 31, 1913.

Recent Progress in the Theoretical Deduction of Airplane Wings, M. Panetti. Nat. Advisory Committee for Aeronautics—Tech. Memorandums, no. 338, Nov. 1925, 10 pp. Deals with problems of wings with uniform and with variable cross-section or profile. Translated from Rivista Aeronautica, July 1925.

AIRSHIPS

Large. Some Matters Relating to Large Airships, G. Fulton. Soc. Nav. Architects & Mar. Engrs.—advance paper, no. 12, for mtg. Nov. 13-14, 1925, 14 pp., 12 figs. on 11 supp. plates; also (abstract) in Mar. Eng. & Shipg. Age, vol. 30, no. 12, Dec. 1925, pp. 702-703. Author thinks there is no room for doubt as to ultimate future of airship as means for bridging long over-water distances, and one thing stands out clearly—use and handling of large airships is intimately bound up with marine knowledge. Includes appendix, giving comparatively characteristics of Shenandoah and Los Angeles.

Rubber Equipment of "Shenandoah." Rubber Equipment of the Shenandoah. India-Rubber Wld., vol. 73, no. 2, Nov. 1, 1925, pp. 69-70, 1 fig. Helium

NOTE.—The abbreviations used in indexing are as follows:

Academy (Acad.)	Engineering (Engr.[s])	Machinery (Machy.)	Record (Rec.)
American (Am.)	Engineering (Eng.)	Machinst (Mach.)	Refrigerating (Refrig.)
Associated (Assoc.)	Gazette (Gaz.)	Magazine (Mag.)	Review (Rev.)
Association (Assn.)	General (Gen.)	Marine (Mar.)	Railway (Ry.)
Bulletin (Bul.)	Geological (Geol.)	Materials (Matls.)	Scientific or Science (Sci.)
Bureau (Bur.)	Heating (Heat.)	Mechanical (Mech.)	Society (Soc.)
Canadian (Can.)	Industrial (Indus.)	Metallurgical (Met.)	State names (Ill., Minn., etc.)
Chemical or Chemistry (Chem.)	Institute (Inst.)	Mining (Min.)	Supplement (Supp.)
Electrical or Electric (Elec.)	Institution (Instn.)	Municipal (Mun.)	Transactions (Trans.)
Electrician (Elecn.)	International (Int.)	National (Nat.)	United States (U. S.)
	Journal (Jl.)	New England (N. E.)	Ventilating (Vent.)
	London (Lond.)	Proceedings (Proc.)	Western (West.)

gas containers and how they are made; gas valves; water ballast and bumping bags.

Schütte-Lanz. Schütte-Lanz Airship Projects after the War, Geo. Weiss. Nat. Advisory Committee for Aeronautics—Tech. Memorandums, no. 335, Oct. 1925, 14 pp., 6 figs. on supp. plates. Deals with few of most conspicuous technical points in airship construction. Translated from Schiffbau, May 27, 1925.

ALLOY STEELS

Electric. Electric Alloy Steel, F. E. Clark. Am. Iron & Steel Inst.—advance paper, for mtg. Oct. 23, 1925, 10 pp. Basic electric process; acid process; general considerations.

[See also SILICON STEEL; TOOL STEEL; VANADIUM STEEL.]

ALLOYS

Aluminum. See ALUMINUM ALLOY.

Brass. See BRASS.

ALUMINUM ALLOYS

Duralumin. See DURALUMIN.

Influence of Various Metals on. On the Influence of Various Metals in Small Quantities On the Nature of Aluminium Alloys, T. Harada. College of Eng.—Memoirs, Kyoto Imper. Univ., vol. 3, no. 9, June 1925, pp. 231–265, 86 figs. on supp. plates. Particulars of research whose aim was based on study of influence of various metals in small quantities upon physical, chemical, and mechanical properties and structure of aluminum, and to obtain some new alloys with improved properties applicable to present-day aluminum industry.

AMMONIA

Specific Heats, Ratio of. Ratio of Specific Heats and Joule-Thomson Coefficient for Ammonia, C. S. Cragoe. Refrig. Eng., vol. 12, no. 5, Nov. 1925, pp. 131–142, 7 figs. It has been shown that experimental data on ammonia obtained at Bur. of Standards and empirical equations used to represent those data as convenient means for computing ammonia tables, yield derived data on specific heat at constant volume and ratio of specific heats which are in good agreement with available experimental data on these properties of ammonia; it has also been shown that derived data on Joule-Thomson coefficient are in substantial agreement with results of throttling experiments on ammonia and with similar results on steam and CO_2 when compared by law of corresponding states.

AMMONIA COMPRESSORS

Lubrication. Notes on the Lubrication of Ammonia Compressors, C. H. S. Tupholme. World Power, vol. 4, no. 23, Nov. 1925, pp. 272–273. Quality of oil is essential property influencing amount of feed necessary for maintenance of proper lubrication and piston seal, and oil of poor quality will do neither; other objectionable results from use of unsuitable oils.

Sleeve-Valve. New Sleeve Valve Compressors at Barking. Cold Storage, vol. 28, no. 311, Oct. 15, 1925, pp. 414–417, 8 figs. Results achieved at ice-making, cold-storage, and ice-cream plant of East London Cold Storage and Ice Co., Ltd., at Barking, where two three-cylinder high-speed compressors of sleeve-valve type have been running almost continuously day and night since April.

Standardization. Standardization of Ammonia Compressors, A. E. Pritchard. Cold Storage, vol. 28, no. 331, Oct. 15, 1925, p. 413. A few suggestions from Australia.

AMMONIA CONDENSERS

Care and Operation. Operation and Care of Ammonia Condensers, H. R. Halterman. Universal Engr., vol. 42, no. 5, Nov. 1925, pp. 24–26. Condensers classified; care and operation; condenser water supply; cooling ponds; cooling towers. Paper read before N.A.P.R.E.

APPRENTICES, TRAINING OF

Self-Supporting System. A Self-supporting Apprenticeship System. Machy. (N. Y.), vol. 32, no. 4, Dec. 1925, pp. 326–328, 4 figs. Features of apprenticeship system conducted by Marion Steam Shovel Co., Marion, O.

AUTOMOBILE ENGINES

Carburetors. See CARBURETORS.

Corrosion. Engine Corrosion—Its Causes and Avoidance, F. Jardine. Soc. Automotive Engrs.—Jl., vol. 17, no. 6, Dec. 1925, pp. 605–606. Corrosion in gasoline engines is generally believed to be due to sulphuric acid formed by combination of sulphur carried in low-grade fuels and oils with water that enters or is generated in engine; only completely successful method of dealing with condensation and rust problem is to provide lubricating system that will begin to function as soon as engine is started; splash system has been found to meet this requirement best; gives recommendations for use of pressure-feed systems.

Design Progress, Germany. Progress in the Design of Automobile Engines (Fortschritte im Motorenbau), Hessler. Automobil-Rundschau, vol. 27, no. 10, Oct. 1925, pp. 202–204, 1 fig. Horch Works have introduced cast-steel sleeve in aluminum cylinder block; block is heated before sleeves are pressed in; sleeves have a flange, center of which does not coincide with center of cylinder; writer believes that springs should be interposed between engine and frame to deaden impact; three-point support would not then be necessary.

Developments. Recent Tendencies in the Field of Automobile Engines (Nutida sträbanden på automobilmotoromradet), E. Hubendick. Teknisk Tidskrift, vol. 55, nos. 38 and 42, Sept. 19 and Oct. 17, 1925, pp. 113–122 and 130–137, 50 figs. Discusses constructive improvements, behavior at maximum compression, size and form of combustion chamber, reduction of piston weight, light metal and cast-iron pistons, fuel consumption, Daimler-Mercedes engine, etc.

Six-Cylindered. Six-Cylinder Commercial-Vehicle Engine. Engineering, vol. 120, no. 3128, Dec. 11, 1925, pp. 738–739 and 742, 4 figs. Details of 6-cylinder engine with side-by-side valves, designated by makers, W. H. Dorman & Co., as 6-J.U. model.

The Small Six-Cylindered Engine. Auto-Motor Jl., vol. 30, no. 20, May 14, 1925, pp. 400–402, 6 figs. Detailed discussion of design.

Spark Plugs. See SPARK PLUGS.

Supercharging. Low-Speed Supercharging (Die Ueberladung von Serien-Automobilmotoren), A. Zoller. Motorwagen, vol. 28, no. 25, Sept. 10, 1925, pp. 537–539, 2 figs. Study of supercharging at low speed for purpose of obviating gear change and improving economy; in author's opinion, supercharger should gradually go out of action so that at high speed there is practically no increase of horsepower with speed; he believes that American method of over-dimensioning engine is out of question for European conditions as it leads to great fuel consumption and unduly heavy chassis.

AUTOMOBILE FUELS

Synthetic. Synthetic Motor Fuels, R. Furness. Indus. Chemist, vol. 1, no. 10, Nov. 1925, pp. 475–580. Production and economic significance of methyl alcohol, ethyl alcohol, benzene, synthol, etc.

AUTOMOBILE MANUFACTURING PLANTS

Equipment, Selection of. How the Automotive Industry Selects Equipment. Machy. (N. Y.), vol. 32, nos. 2, 3, and 4, Oct., Nov., and Dec. 1925, pp. 87–92, 184–189 and 274–276, 20 figs. Deals with important factors considered by equipment engineers in selecting machine tools, small tools, and tooling equipment for production of automobiles, trucks, and tractors.

AUTOMOBILES

Berlin Show. The Berlin Show, B. R. Dierfeld. Automotive Industries, vol. 53, no. 26, Dec. 24, 1925, pp. 1047–1050, 10 figs. Design and price trends influenced by foreign competition; 6-cylinder cars and 6-wheel trucks among exhibit features; growing emphasis on light-car development; new 45-hp. Opel; demonstration of new Knorr automotive air brake for passenger cars; new Daag commercial chassis with individual drive to each rear wheel.

Bodies, Manufacture. Straight Line Production Attained in Wooden Body Building, W. L. Carver. Automotive Industries, vol. 53, nos. 23 and 24, Dec. 3, and 10, 1925, pp. 946–949, and 982–985, 21 figs. Methods used in production of Murray bodies.

Brakes. Pneumatic Brakes for Automobiles (Die Druckluftbremse für Personenfahrzeuge), Th. Kollinek. Motorwagen, vol. 28, no. 27, Sept. 30, 1925, pp. 598–601, 8 figs. Details of Knorr pneumatic brake originally designed for motor trucks and redesigned for use on passenger automobiles; results of tests.

Buick. The 1926 British Empire Buick. Auto-Motor Jl., vol. 30, no. 46, Nov. 12, 1925, pp. 1000–1003, 11 figs. A most popular model of high-class Canadian manufacture; valve-in-head design and four-wheel braking; new clutch; air fuel and lubricant cleaning.

Headlights. Improved Automobile Headlighting, A. W. Devine. Illuminating Eng. Soc.—Trans., vol. 20, no. 9, Nov. 1925, pp. 937–956, 2 figs. Gives short history of development of automobile headlamps and of efforts by state authorities to handle problem of automobile headlighting; outline of problem given and solution offered which is based on improvement in automobile headlamp construction and more stringent specifications for laboratory test; principles upon which approval of electric headlamps by state authorities is based; etc.

Improving Motor Vehicle Headlighting Under the American Standard System, R. N. Falge. Illuminating Eng. Soc.—Trans., vol. 20, no. 9, Nov. 1925, pp. 957–969 and (discussion) 969–980, 10 figs. partly on supp. plates. Outlines development of motor-vehicle head lighting practice and factors that at present make night-driving conditions unsatisfactory; takes up especially limitations of fixed beam system and great advantage to be gained with depressible beams; explains in detail new two-filament lamp for depressible-beam lighting and optical principles involved in its most effective application in equipments.

Report of Committee on Motor Vehicle Lighting—1925, C. H. Sharp. Illuminating Eng. Soc.—Trans., vol. 20, no. 9, Nov. 1925, pp. 929–936. Summarizes briefly progress which has been made in I.E.C. system of headlighting regulation in United States during 1925, and calls attention to added interest being shown in motor-vehicle lighting problems by other organizations; criticisms of present regulations which have resulted from increased interest in problem; discusses, particularly proposal to use a large frosted lamp of greater candlepower than now used, mounted in parabolic reflectors; etc.

Jewett. Lighter Jewett "Six" Announced with Two-Door Sedan at $995, L. S. Gillette. Automotive Industries, vol. 53, no. 23, Dec. 3, 1925, pp. 931–934, 5 figs. All-steel bodies and hydraulic 4-wheel brakes fitted; engine is 4-bearing L-head type with $2^3/_4$-in. bore and $4^3/_4$-in. stroke, developing over 40 hp.

Locomobile. "Model 90" Embodies Many Features New to Locomobile Practice, P. M. Heldt. Automotive Industries, vol. 53, no. 22, Nov. 26, 1925, pp. 894–899, 6 figs. Engine is high-speed type with L-head cylinders, detachable head and pressure lubrication; 4-wheel brakes are standard; wheelbase 138 in., tread $58^1/_4$ in.

Minerva. The 30 H.P. 6-cylinder Minerva Chassis. Automobile Engr., vol. 15, no. 210, Dec. 1925, pp. 434–441, 13 figs. Details of high-grade Belgian car fitted with Knight sleeve-valve engine; power is transmitted through multi-disk clutch to 4-speed gear box which is carried on short subframe; enclosed propeller and spiral bevel axle complete layout, brakes being fitted to transmission and to all 4 wheels; chassis is made in one length.

Peugeot. The 12–35 H.P. Peugeot Car. Auto-Motor Jl., vol. 30, no. 48, Nov. 26, 1925, pp. 1045–1048, 12 figs. Four-wheel braking; wheelbase 9 ft. $4^1/_4$ in., overall length of car 12 ft. 8 in.; monobloc engine having four cylinders with bore of 70 mm. and piston travel of 105 mm.

Pitching. Pitching. Automobile Engr., vol. 15, no. 209, Nov. 1925, pp. 401–405, 5 figs. Fundamental principles affecting interaction of vehicle and suspension.

Transmissions. Arrangement of Mechanical and Hydraulic Power Transmission between Engine and Driving Axle in Motor Vehicles (Anordningar för mekanisk och hydraulisk kraftöverföring mellan motor och drivaxlar å motorfordon), E. Nothin. Teknisk Tidskrift, vol. 55, no. 38, Sept. 19, 1925, pp. 122–128 (Mekanik), 12 figs. Discusses A.E.G., Delavauds, and Constantinesco mechanical types, Föttinger, Lenz, Williams-Janney hydraulic types, their design, construction and operation.

B

BALANCING MACHINES

New Type. A New Balancing Machine, K. Suebiro and L. Kuno. Soc. Naval Architects—Jl., vol. 36, Apr. 1925, pp. 17–22, 15 figs. on supp. plates. (In Japanese.)

BEARINGS

Cylindrical, Temperature and Heat-Loss Calculation. Calculation of Temperatures and Heat Losses in Cylindrical, Ring-Lubricated Bearings (Beräkning av glidlagrets effektförlust och temperatur), S. Hjertén. Teknisk Tidskrift (Mekanik), vol. 55, no. 42, Oct. 17, 1925, pp. 140–142, 3 figs. Short review of latest theoretical and experimental results in this subject.

Oil Film in, Study of. Charts for Studying the Oil Film in Bearings, Geo. B. Karelitz. Am. Soc. Mech. Engrs.—advance paper, for mtg. Nov. 30–Dec. 4, 1925, 22 pp., 14 figs. It has been shown several times that hydrodynamical theory of lubrication satisfactorily explains mechanism of lubrication; charts presented give designer or investigator means of determining with sufficient accuracy shape and pressures in oil film for bearings under different conditions.

BEARINGS, BALL

Bearing Capacity. A False Idea of the Influence of the Number of Balls on the Load-Carrying Capacity of the Cross-Section Ball Bearing (Eine falsche Ansicht über den Einfluss der Kugelzahl auf die Tragfähigkeit der Querkugellager), P. Brühl. Motorwagen, vol. 28, no. 27, Sept. 30, 1925, pp. 589–591, 9 figs. Points out that well-known Stribek formula has not proved satisfactory and assumption that a ball bearing can withstand more in proportion to number of balls it contains (with given external and internal diameter) and in proportion to size of balls, is in this form not correct.

Lubrication. The Lubrication of Ball and Roller Bearings. Commonwealth Engr., vol. 12, no. 12, July 1, 1925, pp. 443–447, 6 figs. Aim of ball and roller bearings is to replace sliding friction by rolling friction, but they must be well lubricated, otherwise they deteriorate rapidly; aim of lubricant is to provide a fluid film between balls and cages, to preserve polished film on surfaces of balls, and to seal bearings against ingress of dust, moisture or corrosive influences where housings are not capable of so doing; points are dealt with.

Roller and. Ball and Roller Bearings, Wm. C. Massie. S. African Instn. Engrs.—Jl., vol. 24, no. 3, Oct. 1925, pp. 46–62, 16 figs. Outlines development of most prominent designs of ball and roller bearings and indicates peculiar advantages possessed by each which give it superiority for certain duties.

Spinning Mules. A Comparison of Ball and Roller Bearings with Plain Bearings by Means of Electrical Tests on a Spinning Mule, W. E. Baker. Textile Inst.—Jl., vol. 16, no. 9, Sept. 1925, pp. T290–T304, 11 figs. Results of test carried out on experimental mule erected at Threlfall's Works in Bolton, England; advantages of ball and roller bearings; electric-power-consumption tests.

BELTING

Leather. Applications of Leather Belting, R. F. Jones. Textile Wld., vol. 67, nos. 14 and 19, Oct. 3 and Nov. 9, 1925, pp. 85, 87, and 89; and 77 and 79, 12 figs. Summary of research work by Leather Belting Exchange Foundation, covering pulley diameter, pulley ratio, center distance between pulleys, effect of high belt speeds, gravity idler, and new rating curves and tables for leather belting.

Determining the Quality of Leather Belting, L. W. Arny. Paper Mill, vol. 49, no. 44, Oct. 31, 1925, pp. 6, 16, and 46, 5 figs. Discusses methods of determining quality and requirements of a good belt.

Leather, Purchasing of. Buying Leather Belting, L. W. Arny. Power House, vol. 18, no. 21, Nov. 5, 1925, pp. 25–26, 5 figs. Points out desirable qualities of high-grade belting and gives practical tests which may be applied to secure them.

Tension Ratio and Transmissive Power. The Tension Ratio and Transmissive Power of Belts, C. A. Norman. Mech. Eng., vol. 47, no. 12, Nov. 1925, pp. 1111–1113, 5 figs. Investigation of increase of transmissive power with slip was conducted on apparatus patterned after that of Friedrich at Ohio State Univ. on rubber, leather, and fabric belts; results of investigation are given in form of curves, and conclusions drawn from tests are noted.

BOILER FEEDWATER

Treatment. Navy Compound, R. S. Twogood. Pac. Ry. Club—Jl., vol. 9, no. 5, Aug. 1925, pp. 21, 23, 25, and 27. Describes Navy compound treatment of boiler water and results of tests.

Zeolite Method, C. W. Sturdevant. Pac. Ry. Club—Jl., vol. 9, no. 5, Aug. 1925, pp. 28–30 and (discussion) 30–39. Advantages of base-exchange softening process, and experiences with zeolite plant in boiler plant of general shops of Southern Pac. Co. in Los Angeles.

BOILER FURNACES

Pulsations, Influence on Combustion. Influence of Pulsations on Combustion, J. Deschamps. Fuels & Furnaces, vol. 3, no. 9, Sept. 1925, pp. 957–958. Transverse movements of air in gas-producer fuel bed created by air pulsations improve operation. Translated from Revue Universelle des Mines.

Radiation in. Radiation in Boiler Furnaces, B. N. Broido. Am. Soc. Mech. Engrs.—advance paper, for mtg. Nov. 30–Dec. 4, 1925, 27 pp., 9 figs. Analysis of fundamentals of radiation and of effect of water-cooled walls on gas temperatures in furnaces; standard curve is drawn which enables designer to determine with sufficient accuracy what part of total heat generated in furnace at different ratings is absorbed by water-cooled walls; this curve can also be used to find heat transmission by radiation per sq. ft. of heating surface for any given conditions of furnace; based on number of installations with water-cooled walls, most advantageous arrangement of such surface for given conditions is suggested; effect of radiation from gases on heat transmission and influence of radiation upon measurement of gas temperatures.

BOILER PLANTS

Instruments. The Fallacy of "Dead Reckoning" in Power Plant Operation, F. Juraschek. Indus. Mgmt. (N. Y.), vol. 70, no. 6, Dec. 1925, pp. 362–366, 6 figs. How even smallest plant can cut its power costs; as instance of what indicating and recording instruments mean to power plant, author cites case of Connecticut manufacturer operating three boilers with total rated capacity of 485 b.hp. and annual coal consumption of 2500 tons; simple corrections in firing methods and damper control resulted in fuel saving of $1540 per year—almost 3 times cost of instruments and changes.

Performance Records. Do you Know How Your Boiler Plant Is Operating? D. Henderson. Indus. Mgmt. (N. Y.), vol. 70, no. 6, Dec. 1925, pp. 334–337. Author cites numerous cases where inaccuracies were responsible for quite meaningless array of records, and shows how to avoid these pitfalls.

BOILER TUBES

Shaping and Heat Treatment. Shaping and Treatment of Boiler Tubes, J. Lang. Eng. Progress, vol. 6, no. 11, Nov. 1925, pp. 363–364, 7 figs. Necessity of high-class workmanship during manufacturing process.

BOILERS

Drill Tests. Drill Tests of Boilers for Wear and Waste, F. J. Drover. Commonwealth Engr., vol. 13, no. 1, Aug. 1, 1925, pp. 11–12. It is claimed that drill-testing of boilers has reduced to a minimum number of boiler explosions in British navy; two chief causes of explosion, shortness of water and fracture through hidden corrosion, explain how useful drill tests are to keep one acquainted with state of boiler; considers all aspects of matter.

Efficiency. What Is Boiler Efficiency? M. A. Rooney. Am. Soc. Heat & Vent. Engrs.—Jl., vol. 31, no. 8, Aug. 1925, pp. 419–422, 3 figs. Makes calculation, in connection with design of boilers for maximum economy; gives curves.

Evaporation Tests. Results of Evaporation Test On a Water Tube Boiler, F. H. Bivens. Gas Age-Rec., vol. 56, no. 19, Nov. 7, 1925, p. 667. Results of an evaporation test made on a water-tube boiler equipped with underfeed stokers; maximum rating obtained was 254 per cent.

Flue Handling. How Two Men Handle 1000 Flues a Week, F. C. Hudson. Am. Mach., vol. 63, no. 25, Dec. 17, 1925, pp. 955–957, 7 figs. Apparatus and methods that enable Grand Trunk shop at Battle Creek to handle boiler and superheater flues at very low cost.

Heating. Testing the Blankenburg Rapid-Circulation Hopper-Fed Boiler (Die Untersuchung des Blankenburg-Schnellumlauf-Füllschachtkessels), Alex. Marx. Gesundheits-Ingenieur, vol. 48, no. 44, Oct. 31, 1925, pp. 557–565, 16 figs. Details of tests of cast-iron heating boiler, arrangement and method of test; and method of calculation of fuel consumption; heat losses; air excess; test data; concludes that new boiler is equal to test in every respect.

High-Pressure. Deformation of Steam Boilers at High Pressure (Zur Deformation der Dampfkessel bei hohem Druck), R. Vogel. Zeit. für angewandte Mathematik und Mechanik, vol. 5, no. 5, Oct. 1925, pp. 389–397, 5 figs. Discusses formation of folds in high-pressure boilers at point of transition from shell to head, and calculates a form of boiler free from this deformation; in which head has a rotary ellipsoidal form.

Locomotive. See LOCOMOTIVE BOILERS.

Rating. Rating Heating Boilers for Hot Blast Service, Chas. L. Hubbard. Domestic Eng. (Chicago), vol. 113, no. 5, Oct. 31, 1925, pp. 20–21 and 45, 4 figs. Methods employed in obtaining usual catalog ratings; in general, these are based on the pound of low pressure steam (about 5-lb. gage) generated per hour, without driving or priming, when using coal having an average calorific value of 13,000 B.t.u. per lb. Considers boiler capacity.

[See also STEAM GENERATORS.]

BORING MACHINES

Cylinder. Duplex Horizontal Cylinder Boring Machine. Machy. (Lond.), vol. 27, no. 686, Nov. 19, 1925, pp. 237–238, 2 figs. Made by Wm. Asquith, Ltd., Halifax, and primarily designed for boring of duplex steam cylinders of 12 in. diameter bore.

The Bignan Cylinder Boring Machine. Machy. (Lond.), vol. 27, no. 687, Nov. 26, 1925, pp. 262–263, 3 figs. Operating principle of machine is to bore by lowering work vertically over set of spindles revolving in fixed bearings; portion of machine itself constitutes boring jig.

Jig. Société Genevoise Locating and Jig Boring Machine. Machy. (N. Y.), vol. 32, no. 4, Dec. 1925, pp. 331–332, 1 fig. Precision machine of considerably larger capacity than previous models built by same company in Geneva, Switzerland.

BRAKES

Foundation. Foundation Brake and Leverage, M. C. Meehan. Car Foremen's Assn. of Chicago—Official Proc., vol. 20, no. 1, Oct. 1925, pp. 32, 35–36, and 39–42, 8 figs. Compilation of data on abuse of foundation brake and consequent destruction of wheels by sliding and means and ways of reducing this waste.

BRASS

Nickel-Manganese. Nickel-Manganese Brasses, Metal Industry (Lond.), vol. 27, no. 20, Nov. 13, 1925, p. 456. Composition recommended; varying equivalent copper-zinc content; mixing, melting, and casting. Abridged translation of paper presented before Franco-Belgian Foundry Congress. See also Foundry Trade Jl., vol. 32, no. 484, Nov. 26, 1925, p. 447.

Rolling, Hot, and Cold. The Hot and Cold Rolling of Brass (Die Warm- und Kalt-Knetbarkeit des Messing), H. Wozelka. Zeit. für Metallkunde, vol. 17, no. 10, Oct. 1925, pp. 334–335, 1 fig. Satisfactory rolling of brass either hot or cold depends on its composition; brass with more that 68 per cent copper can be rolled at any temperature up to 800 deg., but brass with 67 to 65 per cent copper can be rolled only cold, and brass with 64 to 63 per cent copper is relatively brittle at all temperatures; alloy with 60 to 62 per cent copper may be rolled most satisfactorily at 600 deg.; addition of manganese and nickel to brass causes it to behave as though it were richer in copper, where other additions cause it to behave as though it contained less copper than it actually does.

Flux, Use of. Profitable Use of Flux, R. Micks. Can. Foundryman, vol. 16, no. 11, Nov. 1925, pp. 20–21, 1 fig. Points out that there are still many brass founders who fail to see advantage of using good flux when melting their metal; boron sux-oxide is acknowledged to be best flux for copper, while yellow prussiate of potassium has also given good results; chloride of zinc most popular flux for aluminum; fluorspar as flux for nickel.

C

CABLEWAYS

Mine. Ropeways of Compania Espanola de Minas del Rif. Iron & Coal Trades Rev., vol. 91, no. 3009, Oct. 30, 1925, pp. 684–686, 7 figs. Properties of this company, consisting of large and rich ore deposits, are situated about 15 miles from port of Melilla on north coast of Morocco, and to bring ore down to port a railway was constructed up to a point about $1^1/_3$ miles from mines; transport over intervening distance between rail-head and mines is accomplished by aerial ropeways, which have a heavy hourly capacity. Description of installation; operating costs.

Zugspitze Mt., Germany. The Zugspitze Passenger Ropeway, G. Frederick. Indus. Mgt. (Lond.), vol. 12, no. 11, Nov. 1925, pp. 505–506 and 511, 3 figs. Preliminary review of Bleichert-Zuegg aerial ropeway, now in course of construction for conveying passengers to top of Zugspitze, highest peak in Bavarian Alps, having total length of 3380 meters, measured at incline.

CALORIMETERS

Specific Heats of Gases. A Flow Calorimeter for Specific Heats of Gases, N. S. Osborne, H. F. Stimson and T. S. Sligh, Jr. U. S. Bur Standards, pp. 119–151, 13 figs. partly on supp. plates. Design, construction and operation of calorimeter developed for accurate measurement of specific heat of gases at pressures below 100 atmos. and temperatures below 150 deg. cent.

CAR DUMPERS

Loading Coal into Ships. Pennsylvania R. R. Car-Dumper for Loading Coal into Ships. Eng. News-Rec., vol. 95, no. 23, Dec. 3, 1925, p. 907, 1 fig. Cradle operated by d.c. engines instead of by gearing; large sheaves for operating cables.

Sand. Quantity production of Automatic Unloader Cars for Transporting Sand (Reihenanfertigung von Selbstentladewagen für Sandtransport), Werner. Werkstattstechnik, vol. 19, no. 18, Sept. 15, 1925, pp. 656–660, 9 figs. Details of design and construction of cars having a capacity of 60 tons and weighing 16 tons, which for unloading are run onto a side rail, the deviation from the vertical resulting in unloading by tipping.

CAR WHEELS

Manufacture. The Manufacture of Steel Wheel-Centres, Tyres and Axles at Newcastle, N. S. W., Australia, C. M. Anson. Can. Inst. Min. & Metallurgy—Bul., no. 163, Nov. 1925, pp. 1035–1053, 6 figs. Describes processes used in manufacture at works of Commonwealth Steel Products Co.; Heroult electric furnace; forging and rolling; machining, assembly and inspection.

CARBURETORS

Characteristics. Commercial Carburetor Characteristics, C. S. Kegerreis, O. Chenoweth and M. J. Zucrow. Purdue Univ., Eng. Exper. Sta., Bul. No. 21, Aug. 1925, 115 pp., 84 figs. Details and results of investigation carried to determine by actual test how nearly available commercial carburetors meet service demands.

CARS, FREIGHT

Utilization. Utilization of Freight Cars, L. K. Sillcox. Ry. Club of Pittsburgh—Official Proc., vol. 24, no. 8, Sept. 24, 1925, pp. 160–174 and (discussion) 174–192, 1 fig. From viewpoint of loading, design and maintenance.

CARS, PASSENGER

Steel. All-Steel Cars of the New South Wales Railways. Commonwealth Engr., vol. 12, no. 12, July 1, 1925, pp. 440–442, 3 figs. Leading dimensions are generally similar to those of large E.B.B.-type cars on North Shore and Bankstown lines, but arrangement of doorways, interior partitions, and seating accommodation is slightly different; particulars of car.

Main Line Metal Cars for First and Second Class (Voiture métallique mixte de 1[re] et 2[e] classes pour grandes lignes étudiée par l'office central d'études de matérial de chemins de fer), J. Vallancien. Revue Générale des Chemins de Fer, vol. 44, no. 4, Oct. 1925, pp. 263–284, 12 figs. Design and construction of new corridor cars by Central Office for Railway Material Research in France for use on new electrified main and suburban lines; length 20 m., 58 seats; Vickers lighting system, Westinghouse brakes; resistance tests.

CARS, REFRIGERATOR

Intermittent Absorption Machines. Refrigerator Car with Intermittent Absorption Machine, C. H. Herter. Refrigerating Wld., vol. 60, no. 10, Oct. 1925, p. 23. Particulars of individually cooled refrigerator cars equipped with very simple intermittently working absorption machines which are now being built and used in Germany; built by Waggon Fabrik Gebrueder Schonedorff A. G., Duesseldorf, in various sizes and with either two, three or four car axles, and for an ice-melting effect of 1760 to 4400 lb. per 96 hours. Abstracted from Zeit. für Eis und Kälte-Industrie, July 1925.

CASE-HARDENING

Gears. Case-Hardened Gears for Street Cars and Electric Locomotives (Gehärtete Zahnräder für Strassenbahnen und elektrische Lokomotiven), Gräfer. Verkehrstechnik, vol. 42, no. 40, Oct. 1925, pp. 792–793, 7 figs. Discusses basic conditions for faultless working of gears; describes new process of case-hardening by Krupp, in which a hardening powder giving off carbon is placed in a layer 3–4 cm. thick around tool to be hardened which is inserted in a box, heated to 850 deg. and subsequently tempered in oil or water.

Modern Practice. Modern Case-Hardening Practice, F. W. Rowe. Automobile Engr., vol. 15, nos. 209 and 210, Nov. and Dec. 1925, pp. 426–428 and 467–469, 16 figs. Selection and use of materials.

Process. Case Hardening (Die Einsatzhärtung) P. Schweibguth, Werkstattstechnik, vol. 19, no. 18, Sept. 15, 1925, pp. 653–656, 8 figs. Discusses treatment of gun-tool and machine parts such as spring bolts, piston pins, etc., with very hard contact surfaces and soft heads; case-hardening process, hardening powders; annealing depth of penetration, etc.

CAST IRON

Alloy Additions, Effect of. Structures Change with Alloy Additions in Ladle. Foundry, vol. 53, no. 22, Nov. 15, 1925, pp. 927–928, 4 figs. Results of series of experiments carried out at Driver-Harris Co.'s foundry at Harrison, N. J., to determine if addition of material conferred any real benefit on cast iron and to devise method by which addition might be made with minimum amount of trouble and in such manner that amount of each element added might be controlled accurately.

Aluminum, Influence of. The Influence of Aluminium on Cast Iron, A. B. Everest. Brit. Cast Iron Research Assn.—Bul., no. 10, Oct. 1925, pp. 4–6. Review of investigations and bibliography.

Brinell Hardness and Tensile Strength. Brinell Hardness and Tensile Strength of Cast Iron. Brit. Cast Iron Research Assn.—Bul., no. 10, Oct. 1925, pp. 6–9. It is shown that no concordant results are obtained by plotting either actual tensile or actual compression against actual Brinell values; it can be said that as thickness of finger increases, hardness decreases and tensile and compression decrease, but there is no definite relationship connecting the two; formulas proposed by Portevin and Schuz for cast iron give calculated tensile values from Brinell figure 1.5 to 3 times as great as actual tensile value, so that they do not appear to be of any service whatever.

Cupola-Melted Mixed Steel and. Cast-iron and Steel Melting and Mixtures, W. J. May. Mech. World, vol. 78, no. 2030, Nov. 27, 1925, p. 427. Notes on use of steel in making up charges for cupola; generally, steel and iron when in combination should be run rather hot, molds should be as dry as possible, and good body sand should surround casting, which should cool in mold.

Gray, Mechanical Tests. Correlating Gray Iron Tests, J. W. Bolton. Foundry, vol. 53, nos. 22 and 23, Nov. 15 and Dec. 1, 1925, pp. 912–915 and 958–961, 18 figs. Outline of more commonly used tests for gray irons; consideration of more common mechanical tests, related engineering properties and correlation of these tests to observations of structure of gray iron. Author points out that while four major components, pearlite, ferrite, graphite and steadite, may be approximated closely from analysis, still sizes and distribution of grain structures are determined best microscopically. Annual exchange paper prepared under auspices of

Am. Foundrymen's Assn. for presentation before Belgian and French Foundrymen's Associations.

Research. Practical Points from Recent Researches in Cast Iron, B. Rogers. Foundry Trade Jl., vol. 32, no. 483, Nov. 19, 1925, pp. 427–429. Deals principally with those writers who have themselves experimented upon practical lines; factors influencing total carbon; casting temperature. Recommends list of papers as being capable of giving sound information upon study.

Testing. Determining the Mechanical Properties of Castings, H. Thyssen. Mech. World, vol. 78, no. 2025, Oct. 23, 1925, States that ordinary impact, bending and tensile tests are not suitable for determining properties of cast iron; in addition to Brinell hardness test, author recommends slow flexure and shearing tests. Abstract, translated from French.

Thyssen-Emmel Process. Low Carburized Cast Iron Produced in Cupolas, K. Emmel. Am. Metal Market—Monthly Rev. Section, vol. 32, no. 222, Nov. 17, 1925, pp. 3–5, 8 figs. Describes Thyssen-Emmel process; problem has been solved of producing with ordinary cupola a cast iron of total carbon content guaranteed below 3 per cent; nature of process concerns measures in cupola working which revolutionize former conceptions and practice. Translated from Stahl u. Eisen.

CASTINGS

Machine-Made. Guiding Rules for the Production of Clean Machine-Made Castings (Richtlinien für die Erzeugung von sauberem Formmaschinenguss). Zeit. für die gesamte Giessereipraxis, vol. 46, nos. 44 and 45, Nov. 1 and 8, 1925, pp. 517–518 and 526–527. Requirements of molding machine for production of clean castings; molding methods.

CENTRAL STATIONS

Bradford, England. The Bradford Electricity Undertaking. Elec. Rev., vol. 97, nos. 2050 and 2506, Nov. 27 and Dec. 4, 1925, pp. 861–863 and 888–890, 12 figs. Details of 20,000-kw. generating set; new turbine, manufactured by English Elec. Co., is 2-cylinder tandem combination. See also description in Elecn., vol. 95, no. 2479, Nov. 20, 1925, pp. 584–586, 5 figs.

Colfax, Pittsburgh, Pa. Recent Developments at Colfax Station, Duquesne Light Co., Chas. W. E. Clarke. Am. Soc. Mech. Engrs.—advance paper, for mtg. Nov. 30–Dec. 4, 1925, 21 pp., 13 figs. Test results of 3-A element of station which showed net heat rates of 12,750 B.t.u. per kw-hr. at 30,333 kw., 13,021 B.t.u. per kw-hr. at 22,400 kw., and 14,200 B.t.u. per kw-hr. at 15,050 kw.; brief history of physical plant involved in original station and in unit extensions Nos. 1, 2 and 3, with data on boiler and turbine outages and condenser cleaning; total cost of station has been to date $115,80 per kw. for 190,000 kw. of installed capacity.

Hell Gate, New York City. An American Super-Power Station—The Hell Gate Station at New York, J. B. N. Kershaw. World Power, vol. 4, no. 23, Nov. 1925, pp. 245–249, 5 figs. Details of layout and equipment; operating data.

Hydroelectric vs. Steam. Will Hydro Finally Displace Steam Power? L. M. Arkley. Power House, vol. 18, no. 20, Oct. 20, 1925, p. 91. It is demonstrated that hydroelectric power plants will never replace all steam-driven plants, but that there will be a judicious combination of both, in interests of efficiency and economy.

Private Plant, vs. Central-Station Service Most Economical, H. C. Thuerk. Elec. World, vol. 86, no. 22, Nov. 28, 1925, pp. 1112–1114, 3 figs. How careful analysis of hot water required for process work and study of costs with isolated plant showed marked saving by purchasing power.

Steam. Steam Station Design and Equipment, C. F. Hirshfeld. Elec. Light & Power, vol. 3, nos. 11 and 12, Nov. and Dec. 1925, pp. 27–28, 84, 86, 88, 90 and 92; and 25–26, 82 and 84, 6 figs. An analysis of past, present and future trend.

COAL HANDLING

Power Plants. Where Gravity Helps the Power Bill, M. W. Potts. Indus. Mgmt. (N. Y.), vol. 70, no. 6, Dec. 1925, pp. 351–354, 6 figs. Handling coal and ashes at Hammermill paper plant at Erie, Pa.

COMPRESSED AIR

Aircraft Manufacture. Some Typical Uses of Compressed Air in the Manufacture of Aircraft, P. G. Johnson. Compressed Air Mag., vol. 30, no. 11, Nov. 1925, pp. 1429–1432, 13 figs. Mentions some of most striking applications that have proved of especial value to single concern, the Boeing Airplane Co., Seattle, Wash.

CONDENSERS, STEAM

Locomotive. The Locomotive Condenser. Ry. Engr., vol. 46, no. 551, Dec. 1925, p. 433, 1 fig. Survey of various types and their characteristics.

Surface. Efficient Marine Steam-Plant Operation. Mar. Engr. & Motorship Bldr., vol. 48, no. 578, Nov. 1925, pp. 413–415. Practical problems affecting working of surface condensers.

Tubes. Corrosion of Condenser Tubes (Note sur la corrosion des tubes de condenseurs), F. de Wurstemberger. Bulletin Technique du Bureau Veritas, vol. 7, no. 6, June 1925, pp. 101–105, 6 figs. Discusses principle of corrosion of brass by sea-water and describes a method for converting injurious stray currents into currents protecting the metal.

CONVEYORS

Pneumatic. Pneumatic Conveying Plants of Large and Small Capacity (Pneumatic Förderanlagen für grosse und kleine Leistungen), O. Kleier. Fördertechnik u. Frachtverkehr, vol. 18, no. 18, Sept. 20, 1925, pp. 288–289, 5 figs. Design and operation of Luther plant for unloading grain from ships; capacity up to 300 tons per hour; small-grain coal from railway cars, etc.

Types. Modern Conveying in Factory Operation (Neuzeitliche Förderungen in Fabrikbetrieben), O. Hochstetter, Fördertechnik u. Frachtverkehr, vol. 18, no. 16, Aug. 18, 1925, pp. 241–246, 32 figs. Discusses types of chains for conveying and driving, continuous and intermittent; belt conveyors, rocking conveyors and elevators, bucket chains, band conveyors, roller conveyors, coal-handling plants, etc.

COUPLINGS

Shaft, Flexible. Flexible Shaft Coupling. Textile Wld., vol. 68, no. 18, Oct. 31, 1925, p. 53, 2 figs. Describes new type of shaft coupling placed on market by Farrel Foundry & Machine Co., Buffalo, N. Y., called "Sykes universal shaft coupling;" differs from other flexible couplings in that it is really a universal joint and is therefore capable of not only taking care of small errors in alignment but of successfully connecting shafts which are grossly misaligned; its limit of angularity is stated to be 5 deg.

CRANES

Overhead. Traction and Adhesion in the Design of Overhead Cranes. Mech. World, vol. 78, no. 2026, Oct. 30, 1925, pp. 343–345, 4 figs. Deals with question of design of electric traveling cranes from point of view of obtaining satisfactory travel motions.

Steam Titan. 50-Ton Steam Titan Crane. Engineer, vol. 140, no. 3647, Nov. 20, 1925, p. 561, 2 figs. partly on p. 552. Built by Stohert & Pitt, Bath, Eng., for Union of South Africa; it consists of upper structure of double cantilever type which revolves by means of live ring of steel rollers upon truck, which forms full portal for passage of traffic and block trucks.

CRANKSHAFTS

Turning Machines. Crankshaft Turning Machines. Engineering, vol. 120, no. 3128, Dec. 11, 1925, pp. 751–752, 10 figs. partly on supp. plate. In machines which were built by Geo. Richards & Co. of Broadheath, Eng., crankshaft is kept stationary and tools for machining of crankpins are revolved around it.

CUPOLAS

Mechanical Charging. Charges Cupolas Mechanically, Wm. G. Hammerstrom. Foundry, vol. 53, no. 22, Nov. 15, 1925, pp. 908–911, 8 figs. Electric charging device with one operator replaces crew of 8 men on charging platform at Radford, Va., works of Lynchburg Foundry Co., Lynchburg, Va.

CYLINDERS

Aircraft Engines. The Design of Air-Cooled Cylinders, C. F. Taylor. Aviation, vol. 18, nos. 23 and 24, June 8 and 15, 1925, pp. 634–636 and 664–667, 4 figs. Sets forth ideas based largely on results of experiments made by Engineering Division, Air Service, and corroborated in laboratories of Wright Aeronautical Corp.

Lapping. Commercial Cylinderical Lapping, C. T. Appleton. Mech. Eng., vol. 47, no. 12, Dec. 1925, pp. 1106–1110, 6 figs. Cylindrical lapping machine and its operation; production of piston pins; tolerances; conservative rate of commercial lapping; work holders; truing lapping wheels; lapping experiments and conclusions drawn therefrom. Discussion of paper by P. M. Mueller, published in Sept. 1925 issue of Journal.

Lapping. A New Lapping Machine. Automobile Engr., vol. 15, no. 210, Dec. 1925, p. 470, 1 fig. The B.S.A. universal machine for flat and cylindrical parts.

D

DIE CASTING

Large Casting. An Unusually Large Die Casting Produced in a Southern California Plant, Miles C. Smith. West. Machy. World, vol. 16, no. 10, Oct. 1925, pp. 405–406, 6 figs. Describes casting of large piece which is part of body of an agitator for mixing liquids in glass or mixed-drink container; part in question is stand or upright body weighing over 8 lb. when cast of zinc-base alloy metal.

Production and Uses. Production and Use of Die-Cast Parts (Herstellung und Verwendung von Spritzgussteilen), Fr. Ehrmann. Zeit. für Metallkunde, vol. 17, no. 10, Oct. 1925, pp. 329–333, 13 figs. Discusses most important alloys for die casting; horizontal and vertical arrangement of piston machines; American die-casting machine for aluminum; reliable die-casting alloys; grain development with aluminum sand, chill and die casting; examples showing economy of die casting.

DIES

Forming and Embossing. Coining, Forming and Embossing Dies, Machy. (N. Y.), vol. 32, no. 4, Dec. 1925, pp. 294–296, 5 figs. Describes dies which are similar in some respects to drawing dies.

DIESEL ENGINES

Airless-Injection. Diesel Engines with Airless Injection (Dieselmotoren mit luftloser Einspritzung), Kraftmaschine, vol. 22, no. 12, June 25, 1925, pp. 112–114, 7 figs. Details of Deutz Motorenfabrik design, embodying simplest form of combustion chamber, to carry off a minimum of heat; injection of fuel into extremely hot air core for rapid deflagration; long but uniform path of rays to avoid deposit of soot.

Fuel for. Diesel Engine and Its Fuel, L. Wolff. Pac. Mar. Rev., vol. 22, no. 12, Dec. 1925, pp. 558–560, 2 figs. Review of developments in design of Diesel engines; advantages of Diesel operation; question of suitable and adequate fuel supply.

Lubrication. Lubrication of the Diesel, P. Aikens. Power House, vol. 18, no. 20, Oct. 20, 1925, pp. 95–96. Minimizes repairs; oil of correct body; lubrication requirements of air-compressor cylinders; oxidation; lubrication bearings; treatment of oil; contaminated oil; reliability with economy.

Manufacture. Building Diesel Engines for the Panama Canal, F. W. Curtis. Am. Mach., vol. 63, no. 25, Dec. 17, 1925, pp. 959–962, 8 figs. Specifications of units; assembling bedplates; planing cylinders; turning pistons; machining cylinder heads. Built by Nordberg Mfg. Co., Milwaukee, Wis.

Marine. Marine Diesel Machinery, Jas. Richardson. Engineering, vol. 120, no. 3125, Nov. 20, 1925, pp. 639–641, 8 figs. Progress made towards reducing weight of Diesel machinery; double-acting engines; question of greater average speed maintained by motorship, and other advantages. Paper read before Manchester Assn. Engrs. (Abridged.)

Nobel Two-Stroke. 1000 B.H.P. Two-Stroke Diesel Engine. Mech. World, vol. 78, no. 2030, Nov. 27, 1925, pp. 419–420, 2 figs. Describes Nobel 2-stroke type erected in works of Mirlees, Bickerton & Day, Stockport, Eng.

Torsional Vibration. Torsional Vibration in the Diesel Engine, F. M. Lewis. Soc. Nav. Architects & Mar. Engrs.—advance paper, no. 9, for mtg. Nov. 12–13, 1925, 32 pp., 19 supp. plates. Review of more fundamental aspects; calculation of natural frequencies of vibration; vibration in multi-cylinder engine; types of installation and their vibration characteristics; elimination of vibration; speed regulation—action of flywheel. Bibliography.

Worthington The Double-Acting, Two-Cycle Oil-Engine, O. E. Jorgensen. Soc. Nav. Architects & Mar. Engrs.—advance paper, no. 14, for mtg. Nov. 13–14, 1925, 9 pp., 15 figs. on 14 supp. plates. Describes new Worthington engine and compares its method of operation with single-acting engines and double-acting 4-cycle type; comparison is made of weights, power output and heat transfer of different types and of their relative costs; describes features peculiar to Worthington engine; experiments to determine rate of heat transfer in cylinder walls and variations of pressure in piston-rod stuffing boxes. See also discussion in Mar. Eng. & Shipg. Age, vol. 30, no. 12, Dec. 1925, pp. 704–705.

DRILLING MACHINES

Four-Spindle Horizontal. "Asquith" Four-Spindle Horizontal Fire Box and Boiler Shell Drilling Machine. British Machine Tool Eng., vol. 3, no. 35, Sept.–Oct. 1925, pp. 304–307, 4 figs. This machine operates in accordance with modern approved locomotive shop practice, but is capable of a much higher output than single-spindle machine, output of which is limited by capacity of one drill spindle.

Rotating Tables on Multiple. Using Rotating Tables on Multiple Drills, W. F. Sandmann. Machy. (N. Y.), vol. 32, no. 4, Dec. 1925, pp. 310–312, 6 figs. Combined drilling and tapping machines; combined drilling and reaming operations; set-up for drilling closely spaced holes; fixed type of bushing plate.

DURALUMIN

Deterioration, in "Shenandoah." Deterioration of Duralumin in the "Shenandoah." Eng. News-Rec., vol. 95, no. 25, Dec. 17, 1925, pp. 1000–1001. Results of Bur. of Standards tests brought out before court; intercrystalline corrosions widespread.

Treatment. The Duralumin Problem (Das Duraluminproblem), W. Fraenkel. Zeit. für angewandte Chemie, vol. 38, no. 33, Aug. 13, 1925, pp. 696–699, 1 fig. Discusses scientific problem of improving aluminum alloys by heat treating, hardening, tempering, etc.; increase of tensile strength, mixed crystal formation, electric conductivity, etc.

E

EDUCATION, ENGINEERING

Colleges, Opportunity for Service. The Engineering College—Its Opportunity for Service, A. A. Potter. Jl. Eng. Education, vol. 16, no. 1, Sept. 1925, pp. 4–24. Points out that industry and engineering colleges are interdependent; outstanding characteristics of engineering colleges; technique of engineering education; concentric methods of engineering education; instruction along functional lines; commercial training; character building and development of personality; guiding students to discover their aptitudes; cultural training; research as aid to engineering education.

German Association for Technical Instruction. Technical Works Instruction in Germany. Engineering, vol. 120, no. 3128, Dec. 11, 1925, p. 752. Organization and aims of the DATSCH (Deutsche Ausschuss für Technisches Schulwesen), which has become central office for intermediate technical instruction, training of apprentices and employees, coming from ordinary or trade schools and intending to proceed in due time to technical high schools.

Graduates and Teaching Personnel. Engineering Graduates and Engineering Teaching Personnel. Mech. Eng., vol. 47, no. 12, Dec. 1925, pp. 1181–1197, 4 figs. Reports of committees of Soc. for Promotion of Eng. Education as follows: Report of Committee on Engineering Students and Graduates, June 1, 1925; Preliminary Report of Committee on Teaching Personnel.

Research and. The Relation between Engineering Education and Research, R. W. Sorensen. Am. Inst. Elec. Engrs.—Jl., vol. 44, no.12, Dec. 1925, pp. 1288–1290. With particular reference to California Inst. of Technology plan.

Students and Graduates. Society for the Promotion of Engineering Education, Report of Committee on Engineering Students and Graduates. Jl. Eng. Education, vol. 16, no. 1, Sept. 1925, pp. 75–84, 3 figs. Results of study based upon returns covering approximately 4000 individual students attending 32 institutions; secondary school preparation; educational guidance of entering students; conclusions.

ELECTRIC DRIVE

Sectional. The Evolution of the Sectional Drive, H. W. Rogers. Paper Trade Jl., vol. 81, no. 18, Oct. 29, 1925, pp. 99–102, 5 figs. Discusses horsepower per ton daily, influence of drive on product, exacting requirements, two types of drives and difference between the types, stages of development, etc.

ELECTRIC FURNACES

Conversion from Oil-Fired Furnace. Converting an Oil-Fired Furnace to Electric Heating, W. J. Walsh. Elec. World, vol. 86, no. 22, Nov. 28, 1925, pp. 1110–1111, 2 figs. Describes reconstruction of oil-fired unit consisting of 3 heating chambers; Leeds & Northrup 2-point special gun furnace control was adopted; check-up of cost of both types of operation.

ELECTRIC LOCOMOTIVES

Diesel-Electric. Comparative Tests with Diesel and Steam Locomotives. Eng. Progress, vol. 6, no. 10, Oct. 1925, pp. 319–320, 7 figs. Results of comparative tests conducted in November 1925, on Russian test bed at Maschinenfabrik Esslingen with first 1-E-1 Diesel-electric locomotive of Russian Government Rys. and one of 700 Russian E-coupled freight engines built in Germany; results showed savings of fuel with Diesel locomotive.

Oil-Electric. Oil-Electric Switching Locomotive of 100 Tons Weight Developed for Long Island Railroad. Ry. & Locomotive Eng., vol. 38, no. 11, Nov. 1925, pp. 328–329, 2 figs. 100-ton locomotive will have 2 oil-engine-driven generator sets to furnish power to 4 direct-current, geared traction motors; engines, manufactured by Ingersoll-Rand Co., are 6-cylinder, vertical units of 4-cycle type, with piston of 10-in. diam. and 12-in. stroke.

Rough Use. Electric Locomotive for Rough Operations (Elektrische Lokomotiven für rauhe Betriebe), Passauer. Elektrische Bahnen, vol. 1, no. 9, Sept. 1925, pp. 344–348, 9 figs. Discusses suitability of electric locomotives because of absence of main and side rods, and possibility of enclosing all parts to make them dust- or waterproof; examples of rough usage in metallurgical works, etc.

Types. Viewpoints of Economy and Design in the Construction of Recent Large Electric Locomotives (Wirtschaftliche und konstruktive Gesichtspunkte im Bau neuerer Gross-Elektrolokomotiven), A. Laternser. Schweizerische Bauzeitung, vol. 86, no. 21, Nov. 21, 1925, pp. 253–256, 20 figs. Comparison and principal data of locomotives of Italian, Norwegian, Swedish, Swiss, Chilean, Mexican, Brazilian, South African State, and Pennsylvania railways; comprise six American 3000-volt d.c., one European 3000-volt d.c., one American two-phase 3300-hp. for monophase 22,000 volts 25 cycle/d.c., one European rotary current 2560-hp. for 3600 volts 45 cycle, and 7 European 15,000 volts $16^2/_3$ cycle monophase types.

ELECTRIC RAILWAYS

Car Design. Report of Committee on Unification of Car Design. Elec. Traction, vol. 21, no. 10, Oct. 1925, pp. 535–536. Report to Am. Elec. Ry. Assn.

Chicago, North Shore & Milwaukee R. R. North Shore Speeds Service. Elec. Traction, vol. 21, no. 11, Nov. 1925, pp. 582–586, 6 figs. 36 mi. of new double-track being constructed by Chicago, North Shore and Milwaukee R. R. through Skokie Valley as cut-off for high-speed service.

ELECTRIC WELDING, ARC

Costs. Arc Welding Costs, K. R. Hare. Am. Welding Soc.—Jl., vol. 4, no. 9, Sept. 1925, pp. 17–19, 1 fig. Presents table showing pounds of metal deposited per hour with different heat values and different sizes of electrodes, from which it is apparent that there is distinct advantage along lines of increased production in using larger sizes of electrodes wherever possible.

Manufacturing Process. Arc Welding as a Manufacturing Process, H. M. Hobard and W. Spraragen. Am. Welding Soc.—Jl., vol. 4, no. 10, Oct. 1925, pp. 71–103, 15 figs. Deals with fundamental considerations, such as design, material, welding rods, jigs and fixtures, inspection, testing, cost data, speed of arc welding, etc., examples of arc-welding applications; use of arc welding in Westinghouse Elec. & Mfg. Co.'s works.

Portable Multi-Operator Plant. Portable Multi-operator Electric Arc Welding Plants. Engineer, vol. 140, no. 3647, Nov. 20, 1925, p. 550, 2 figs. New type of equipment placed on market by Premier Elec. Welding Co., London, designed to furnish welding current to several operators at same time without use of large resistances.

Weldability of Ferrous Metals. Metallic Arc Weldability of Ferrous Metals, C. J. Holslag. Am. Welding Soc.—Jl., vol. 4, no. 10, Oct. 1925, pp. 37–43. Discusses weldability of various alloy steels, cast iron, malleable iron, and cast steel.

ELECTRIC WELDING, RESISTANCE

Non-Ferrous Metals. Welding of Non-Ferrous and Special Metals by the Resistance Welding Process, H. A. Woofter. Am. Welding Soc.—Jl., vol. 4, no. 9, Sept. 1925, pp. 46–49. Notes on welding of aluminum brass, copper, duralumin, monel metal and special metals.

Spot and Seam. Prescot Spot and Seam-Welding Machines. Engineering, vol. 120, no. 3127, Dec. 4, 1925, pp. 724–726, 9 figs. Salient features of two types of machines, made by Brit. Insulated & Helsby Cables, Ltd., Prescot, Lancashire, Eng.

Welding All Steel Automobile Bodies, Jos. W. Meadowcroft. Am. Welding Soc.—Jl., vol. 4, no. 10, Oct. 1925, pp. 43–57, 6 figs.; also (abstracts) in Welding Engr., vol. 10, no. 11, Nov. 1925, pp. 27–29. Spot welding extensively used in body building; development of special devices useful in spot welding; tests; instructions to electric-spot-welding operators; strength of spot welds.

ELEVATORS

Fault Location. Locating Faults in Electric Elevators—Direct-Current Controllers, Chas. A. Armstrong. Power, vol. 62, nos. 18, 20 and 25, Nov. 3, 17 and 22, 1925, pp. 674–677, 4 figs.; 760–763, 6 figs.; and 969–972, 13 figs. Nov. 3: Faults that may cause main fuses to blow and make potential switch fail to function properly. Nov. 17: Faults in controllers of mechanically controlled elevators that may cause motor to start or fail to come up to speed if it does start. Dec. 22: Faults in full-magnet-type controllers.

EMPLOYEES' REPRESENTATION

Works Councils. Works Council Movement in Germany, B. Stern. U. S. Bur. of Labor Statistics, no. 383, Mar. 1925, 114 pp. Origin of movement; history and nature of works-council law; purpose and scope of law; workers' representation in single establishments; other forms of workers' representation; problems of organization; functions of workers' representatives; works councils and collective bargaining; boards of adjustment and labor courts; special rights of workers' representatives; works councils and German trade unions; 4 years of works councils in German industry; movement in other European countries. Bibliography.

ENAMELING

Pistol Spray for. The Aerograph Pistol Spray. Engineering, vol. 120, no. 3123, Nov. 6, 1925, pp. 590–591, 1 fig. Describes latest design of pistol spray introduced by Aerograph Co., London; it is known as G. P. model and is particularly suitable for cellulose enamels, but may also be used for general purposes with ordinary paints and varnishes.

ESCALATORS

Italy. Escalators for the Urban Section in Naples of the Rome-Naples Express (Scale mobili per il tratto urbano in Napoli della direttissima Roma-Napoli), E. D'Andrea. Rivista Tecnica delle Ferrovie Italiane, vol. 28, no. 4, Oct. 15, 1925, pp. 129–137, 9 figs., partly on supp. plates. Details of design and construction of escalator plants at Montesanto and Cavour subway stations, mechanical and electric equipment, power consumption, etc.

EVAPORATORS

Power-House. Power-house Evaporators, D. McHutchison. Mech. World, vol. 78, no. 2028, Nov. 13, 1925, pp. 382–383, 2 figs. Discusses design, developments and types.

F

FACTORIES

Buildings. The Modern Manufacturing Plant. Mgmt. & Admin., vol. 10, no. 6, Dec. 1925, pp. 339–342, 3 figs. E. R. Squibb & Sons complete first unit of thoroughly planned new building program at Brooklyn plant.

Planning. Some Problems in Works Planning, A. Whitehead. Mech. World, vol. 78, nos. 2028 and 2029, Nov. 13 and 20, 1925, pp. 387–388 and 406–407, 4 figs. Consideration of such problems as labor supply, space for extension, form of building, arrangement of machines, lighting and heating.

FANS

Problems. Fan Problems, H. Briggs. Colliery Eng., vol. 2, nos. 15, 16, 17, 18, May, June, July, and Aug. 1925, pp. 197–199, 245–248, 292–294 and 367–369, 13 figs. May: Notes on efficiency and cost of power; need for effective criticism; causes of exaggerated efficiencies; inaccuracies in measurement of volume; plea for manometrical efficiency; what happens when fan speed is varied. June: Characteristic curves; natural ventilation; mine characteristic and natural ventilation; measuring resistance of fan. July: Flow of air in converging and expanding channels; purpose of evasee, its shape and efficiency. Aug:. Power available for conversion by evasee; venturi blowers and velocity indicators.

FEEDWATER HEATERS

Locomotive. Committee Report on Feed Water Heaters. Ry. Rev., vol. 77, no. 23, Dec. 5, 1925, pp. 853–859, 7 figs. Discussion of open and closed types, exhaust steam injectors and direct methods for steaming locomotives. (Abstract.) Report of Int. Ry. Fuel Assn.

FLOW OF AIR

Rotating Cylinder, around. Flow of Air Around a Rotating Cylinder, E. N. Fales. Air Service Information Circular, vol. 6, no. 510, June 1, 1925, 4 pp., 6 figs. Test made as simple means of demonstrating change of air flow about cylinder when latter is rotating.

Transmission of Waves through Pipes. On the Transmission of Air-Waves through Pipes, L. F. G. Simmons and F. C. Johansen. Lond., Edinburgh, & Dublin Philosophical Mag. & Jl. Sci., vol. 50, no. 297, Sept. 1925, pp. 553–570, 8 figs. Results of experiments, conducted at Nat. Physical Laboratory on transmission of waves through rubber pipes, which deal with propagation of single wave resulting from sudden application of known pressure at one end of pipe, and with waves generated by simple harmonic variation of pressure of displacement, applied at one end; results pertaining to closed pipes indicate relationship existing between pressures at any instant at two ends, and extent to which these are affected by size and length of pipe, and by type of gage used; measurements of displacement made at end of open pipes may be compared with calculations based on theory given by Rayleigh.

FLOW OF FLUIDS

Resistance of Viscous Fluids. A Note on Resistance to Flow of Viscous Fluid, K. Suyehiro. Soc. Naval Architects—Jl., vol. 36, Apr. 1925, pp. 87–92, 12 figs., partly on supp. plates. (In English.)

FLOW OF WATER

Surge Tanks. The Surge Tank of Constant Area. H. W. Coultas. World Power, vol. 4, no. 23, Nov., 1925, pp. 259–263, 3 figs. Principle of similarity applied to surge tank.

FLUE-GAS ANALYSIS

CO_2 and CO Recorders. Developments in Flue-Gas Analysis. Power Engr., vol. 20, no. 236, Nov. 1925, pp. 430–432, 9 figs. Description of Cambridge combined CO_2 and CO instruments.

FLYING BOATS

C. A. N. T. Static Tests of Flying Boats C. A. N. T. 10 ter and C. A. N. T. 12 (Prove statiche degli impennaggi degli idrovolanti C. A. N. T. 10 ter and C. A. N. T. 12). Rendiconti Tecnici della Direzione Superiore del Genio e delle Construzioni Aeronautiche, vol. 13, no. 7, Aug. 15, 1925, pp. 1–5, 4 figs. on supp. plates. Report of Aeronautical Commission on tests of boats constructed by Cantiere Navale Triestino de Monfalcone; C. A. N. T. 10 ter has total weight of 2650 kg., and maximum speed of 175 km.p.h.; C. A. N. T. 12 has total weight of 1450 kg., and maximum speed of 180 km.p.h.

Rohrbach. The Rohrbach Flying Boat (Das Rohrbach-Flugboot Ro III), A. Gymnich. Motorwagen, vol. 28, no. 25, Sept. 10, 1925, pp. 543–547, 12 figs. Details of Ro III Rohrbach monoplane flying boat, in which tubular connections are entirely avoided; easily riveted structure parts are used throughout; wings have uniform section from end to end; it has two 360-hp. Rolls-Royce engines side by side, which gives improved turning ability on water; built of duralumin.

FLYWHEELS

Internal-Combustion Engines. Flywheels for Otto Cycle Horizontal Internal-Combustion Engines. Power Engr., vol. 20, no. 236, Nov. 1925, pp. 413–416, 9 figs. Presents reasonable basis for computation of weight of flywheels necessary for multi-cylinder engines.

FORGE SHOPS

Economies in. Effecting Economies in a Forge Plant, Jos. Haas. Forging—Stamping—Heat Treating, vol. 11, no. 11, Nov. 1925, pp. 397–398. Cites several examples to show how production costs can be reduced; experienced foremen should be placed in charge of all departments.

FORGING

Cold Heading. Cold Heading. Machy. (Lond.), vol. 27, nos. 683, 684, 685, and 686, Oct. 29, Nov. 5, 12 and 19, 1925, pp. 129–134, 161–168, 193–196, and 225–228, 33 figs. Recent developments in cold-heading machines and cold-headed products; manufacturing practice in the production of cold-headed parts.

The Physical Aspect of Cold Heading and Cold Heading Material, C. E. Hill. Machy. (Lond.), vol. 27, no. 687, Nov. 26, 1925, pp. 265–269, 14 figs. Chemical analysis of material for cold heading; heat treatment during manufacture; cold work during heading process; tests applicable to material.

FOUNDRIES

Crucible Cost Reduction. How to Cut Crucible Costs. Metal Industry (N. Y.), vol. 23, no. 11, Nov. 1925, pp. 449–450. Notes on unpacking, storage, storage oven, dampness, preheating, annealing, furnace tending, fuels, pouring, tongs, and shanks; crucibles for various conditions and mixtures. Abstract from pamphlet published by Plumbago Crucible Assn.

Heavy Work. Heavy Work Demands Skill, P. Dwyer. Foundry, vol. 53, no. 23, Dec. 1, 1925, pp. 946–950, 11 figs. Methods and equipment in Longue Pointe plant of Can. Steel Foundries, Ltd.; how waterwheels are molded and cast; varied line of castings are made.

FUELS

Oil. See OIL FUEL.

FURNACES, HEAT-TREATING

Recuperative. Recuperation in Carbonizing Steel, P. W. Hay. Forging—Stamping—Heat Treating, vol. 11, no. 11, Nov. 1925, pp. 403–404, 1 fig. Describes gas-fired carbonizing furnace which constitutes part of equipment in heat-treating department of Buda Co. of Harvey, Ill.; recuperators in each stack comprises 8 sections arranged in 2 tiers; results of tests made to ascertain results obtained with recuperators.

G

GAGES

Micro, Water-Column. Water Column Micro-Gauges, E. Stach. Eng. Progress, vol. 6, no. 10, Oct. 1925, p. 318, 1 fig. Describes minimeter, manufac-

tured by Askania Works, Berlin-Friedenau, Germany designed to cope with maximum of 120 mm. water cap. of either vacuum or head above atmospheric; permits reading of results down to 0.05 mm. with naked eye.

GAS PRODUCERS

Operation. Operation of Gas Producers, F. S. Bloom. Fuels & Furnaces, vol. 3, no. 11, Nov. 1925, pp. 1227–1229, 2 figs. Factors determining capacity of gas producer and quality of gas produced.

Tin-Plate Plant. Producer Gas Used in Tin House. Iron Trade Rev., vol. 77, no. 25, Dec. 17, pp. 1535–1537, 4 figs. Plant for gasifying and cleaning 3000 lb. of bituminous coal an hour is installed by tin-plate producer in Pittsburgh district; tar is extracted from raw gas and utilized beneath boilers. See also description by R. A. Fiske, in Iron Age, vol. 116, no. 25, Dec. 17, 1925, pp. 1665–1668, 6 figs.

GEAR CUTTING

Machines, Special Uses for. Special Work on Gear-cutting Machines. Machy. (N. Y.), vol. 32, no. 4, Dec. 1925, pp. 289–292, 11 figs. Use of gear-cutting machines for drilling and milling, and application of gear generators for special operations.

Sykes Generator. The Sykes Herringbone Gear Generator. Blast Furnace & Steel Plant, vol. 13, nos. 11 and 12, Nov. and Dec. 1925, pp. 456–458 and 497–498, 8 figs. Most interesting features connected with Sykes machines is method of cutting herringbone and double helical teeth, having right and left hand portions of teeth joined at center of face without any clearance whatever for cutting tools; operations in production of Sykes double helical continuous tooth gears.

GEARS

Housings, Machining. Machining the Bevel-Gear Housing of the Mack Truck and Bus, F. W. Curtis. Am. Mach., vol. 63, nos. 22 and 23, Nov. 26 and Dec. 3, 1925, pp. 841–844 and 883–886, 20 figs. Methods adopted by Int. Motor Co. in its New Brunswick, N. J. plant for manufacturing of its bevel-gear housing; large trunnion drill jig; method of driving studs; inspecting work in group form; variety of gages used.

Normal Pitch. Normal Pitch—the Index of Gear Performance, G. M. Eaton. Am. Soc. Mech. Engrs.—advance paper, for mtg. Nov. 30–Dec. 4, 1925, 27 pp., 20 figs. Brings out certain departures from previously accepted practice which are useful in manufacture of heavy involute gearing, as they ease performance during breaking-in stage of operation; shows that material improvement in performance may be secured by adopting proper relation between normal pitches of driving and driven gears, measured at point of tooth engagement; outlines the development of normal-pitch indicators.

Spur, Speed Reducers. Data for Selection of Spur Gear Speed Reducers, F. A. Emmons. Belting, vol. 27, no. 4, Oct. 1925, pp. 40, 42, and 44, 5 figs. Importance of careful calculating actual torques on driven unit, as a basis of determining horsepower required to move load.

Use of Planetary Spur Gear Speed Reduction Units, A. A. Ackley. Belting, vol. 27, no. 4, Oct. 1925, pp. 19–24, 9 figs. Discussion of principles of their construction and operation, and advantages in actual service.

Teeth. Transmission of Work and Efficiency in Gear Wheels (Arbeitsübertragung und Wirkungsgrad bei Zahnrädern), K. Kleinn. Maschinenbau, vol. 4, no. 19, Sept. 17, 1925, pp. 931–934, 7 figs. Discusses a simple method of determining work of teeth and stresses occurring in their passage, and determining efficiency, taking into consideration frictional losses.

Teeth, Wear Experiments. Some Comparative Wear Experiments on Cast-Iron Gear Teeth, G. H. Marx, L. E. Cutter, and B. M. Green. Am. Soc. Mech. Engrs.—advance paper, for mtg. Nov. 30–Dec. 4, 1925, 37 pp., 22 figs. Results of experiments made in laboratories of Stanford Univ.; deductions indicated by tests are as follows: standard-depth 20-deg. involute tooth form appears to be better one to resist wear than standard-depth 14 1/2-deg. involute form; stub-tooth, 20-deg. involute tooth form appears to be better than standard-depth 14 1/2-deg. involute form; standard-depth 20-deg. involute tooth form appears to be better than the stub-tooth 20-deg. involute form; etc.

Varying-Center-Distance. Varying-Center-Distance Gears, H. Walker. Am. Mach., vol. 63, no. 22, Nov. 26, 1925, pp. 853–856, 6 figs. Calculations for design of varying-center-distance gears; methods for avoiding undercutting; tooth-thickness and pressure-angle formulas.

GRAIN HANDLING

Floating Pneumatic Plants. Floating Pneumatic Grain Handling Plant at Cardiff. Indus. Mgmt. (Lond.), vol. 12, no. 11, Nov. 1925, pp. 507–511, 5 figs. Describes plant which has been installed at port of Cardiff, Wales; advantages are speedy, convenient, and dustless operation; capacity 120 tons per hour.

GRINDING MACHINES

Axle Journal Retruing and. Churchill Axle Journal Re-truing and Grinding Machines. British Machine Tool Eng., vol. 3, no. 35, Sept.-Oct. 1925, pp. 308–310, 3 figs. With this machine, axle journals may be maintained in a uniformly excellent condition, being returned whenever their deterioration impairs their efficiency without unduly curtailing their useful life in service.

Internal. "Hydroil" Heavy-Duty Internal Grinding Machine. Machy. (N. Y.), vol. 32, no. 4, Dec. 1925, p. 331, 1 fig. Holes up to 16 in. in diam. and 15 in. in depth can be ground on No. 28 "Hydroil" internal grinding machine made by Greenfield Tap & Die Corp.

H

HEAT TRANSMISSION

Convection. Film Effect and Influence of Wall Vibration on Heat Transmission by Convection (Etude sur l'effect de film et l'influence des vibrations des parois sur la transmission de la chaleur par convection), Ch. Roszak and M. Vernon. Société des Ingénieurs Civils de France—Mémoires et Compte Rendu des Travaux, vol. 78, no. 7–8, July-Aug. 1925, pp. 584–618. Discusses mechanics of process of convection, including simultaneous mechanical flow and heat flow, film phenomenon, interior and exterior circulation, role of film; effect of wall vibration; experimental study of this effect on heat transmission between two fluids which it separates; concludes that wall vibration favors ebullition and vapor-bubble formation, accelerates turbulent flow and heat transmission at low flow, especially in gaseous media, etc.

HEATING

Radiators, Heating Effect of. The Heating Effect of Radiators, C. W. Beabbée. Am. Soc. Heat. & Vent. Engrs.—Jl., vol. 31, no. 11, Nov. 1925, pp. 501–517 and (discussion) 518–520, 12 figs. Describes a practical method for testing radiators by comparison.

HEATING AND VENTILATION

Superpower Plant. Heating and Ventilating a Super-Power Plant, S. Sayward. Domestic Eng. (Chicago), vol. 113, no. 6, Nov. 7, 1925, pp. 22 and 24, 6 figs. Problems in connection with heating and ventilating of Weymouth power station of Edison Elec. Illuminating Co. of Boston, a steam station of most modern design.

HEATING, ELECTRIC

Appliance for Industrial Use. Types of Electric Heating Appliances for Industrial Use, Rob. M. Keeney. Chem. & Met. Eng., vol. 32, no. 17, Nov. 1925, pp. 855–859, 7 figs. Discusses various designs of heaters and their application, with some remarks on heating control and purchase of equipment.

High-Tension. Maximum Prices for Electric Heat (Höchstpreise für Elektrowärme), Windel. Elektrotechnische Zeit., vol. 46, nos. 46 and 47, Nov. 12 and 19, 1925, pp. 1721–1725 and 1771–1775, 2 figs. Develops formulas and gives examples of cost of high-tension current compared with gas, coal, and wood, and gives complete table of calculations for various uses of heat; explanation of table concludes that high-tension heating is quite capable of meeting competition.

Industrial. General Application Data on Industrial Electric Heating. Nat. Elec. Light Assn., Serial Report of Power Committee, Pub. No. 25–54, Aug. 1925, 4 pp. Points out some of the steps in development of industrial electric heating, reasons for this work and what general plan of future development appears to be, dealing with resistance-type heating medium almost entirely.

HEATING, GAS

Costs. Method of Comparing Cost of Central Heating by Anthracite and by Gas (Méthods de comparison des prix de revient du chauffage central, à l'anthracite et au gaz), G. Richard. Journal des Usines à Gaz., vol. 49, no. 20, Oct. 20, 1925, pp. 307–313, 7 figs. Discusses advantages of gas; develops alignment charts for graphic calculation of cost from price of fuel and its calorific value, efficiency of boilers, etc., time of operation and wages and depreciation of plant, showing superiority of gas, especially in mild weather.

HOBBING MACHINES

Automatic Gear. Automatic Gear Hobbing Machine. Machy. (Lond.), vol. 27, no. 687, Nov. 26, 1925, pp. 282–283, 5 figs. Describes most recent machines being placed on market by firm of Schuchardt Schütte, Germany.

HOISTS

Electric Locomotive. Portable Electric Locomotive Hoists. Engineering, vol. 120, no. 3124, Nov. 13, 1925, pp. 602–603, 27 figs. partly on p. 610. Details of type of power hoist made by Ransomes & Rapier, London.

HYDRAULIC PRESSES

Control Valves for. Control Valves for Hydraulic Presses. Machy. (Lond.), vol. 27, no. 687, Nov. 26, 1925, pp. 273–275, 8 figs. Notes on control valves of screw-down type for operating presses from pump or accumulator.

HYDRAULIC TURBINES

Developments. Progress in Design of Hydraulic Turbines Since the War (Progresos en la construccion de turbinas hidraulicas des de la guerra mundial), J. M. Voith. Energia Electrica, vol. 27, nos. 12, 13, 14, 15, 16, 17, 18, 19, and 20, June 25, July 10, 25, Aug. 10, 25, Sept. 10, 25, Oct. 10 and 25, 1925, pp. 157–162, 179–183, 192–195, 206–209, 225–228, 244–245, 258–259, 273–275, and 290–292, 44 figs. Details of turbine installations for small and medium heads built by Voith of Heidenheim; Francis turbines with vertical axis; lubrication; Kaplan turbines with vertical axis at Siebenbrunn central station; Kaplan turbines at Auerhammer central station; Amlezten Heller central station with somewhat larger head using high-speed Francis turbines coupled direct to generator; Francis turbines with horizontal axis; power plants of Froendenberg and Raanaasfoss; power plant at Mauer; Hirten Holzfeld central; Kaplan propeller turbines.

Governors. Hydraulic Turbine Governing—General Principles, S. L. Kerr. Power, vol. 62, no. 25, Dec. 22, 1925, pp. 976–979, 6 figs. Outlines characteristics that good governor must possess, how these are incorporated in governor, and shows what takes place in various parts of hydraulic system when full load or half load is taken off the unit.

High-Speed. High-Speed Capacity and Efficiency of Modern High-Speed Turbines (Schnellâugigkeit und Wirkungsgrade moderner Schnelläuferturbinen), W. Zuppinger. Schweiz. Elektrotechnischer Verein—Bul., vol. 16, no. 8, Aug. 1925, pp. 445–450, 7 figs. Discusses high-speed capacity of Francis, Kaplan and other turbines, showing that, with regard to quantity of water, propeller turbines have a much lower efficiency, choke of favorable high-speed types; proposes new type of two-wheel turbine giving 85 per cent, 80 per cent, 70 per cent efficiency at full, half and quarter load.

Impulse. Hydraulic Impulse Turbines (Turbinas hydraulicas de Impulsão), Greenwood. Revista Brasileira de Engenharia, vol. 10, no. 4, Oct. 1925, pp. 117–131, 17 figs. Discusses developments in turbine design generally and that of impulse turbines in particular; speed regulation; vertical and horizontal arrangements, with examples.

Kaplan. Kaplan Turbines or Propeller Turbines? (Kaplanturbin eller propellerturbin?), E. Englesson. Teknisk Tidskrift, vol. 55, no. 33, Aug. 15, 1925, pp. 67–111 (Mekanik), 23 figs. Discusses efficiency, performance and field of application of both turbines; details of tests carried out, water losses of propeller, Kaplan and Francis turbines; performances with various heads of water, safety in operation, etc.

Present state of Kaplan Turbines and Propeller Turbines (Der heutige Stand der Kaplanturbine und Propellerturbine), C. Reindl. Elektrotechnische Zeit., vol. 46, no. 42, Oct. 15, 1925, pp. 1581–1584, 9 figs. Compares efficiency and design of Kaplan propeller and Francis turbines; details of Kaplan-turbine installation at Siebenbrunn, Ulm, etc.; vertical and horizontal types; propeller turbines of Kachlet plant, etc., showing superiority of Kaplan type.

Pelton Wheels. Design of Pelton Wheel by Means of Specific Speed, K. Minamioji and Y. Yokoyama. Soc. Mech. Engrs.—Jl., Tokyo, Japan, vol. 28, no. 100, Aug. 1925, pp. 471–488, 11 figs. Some practical notes on design of Pelton wheel by means of specific speed, n_s expressing wheel ratio, number of buckets and ridge inclination as functions of n_s and therefrom drawing standard jet diagram to determine chief dimensions of wheel. (In Japanese, with English abstract.)

Turgo. A New Design of Water Wheel. Elec. Rev., vol. 97, no. 2504, Nov. 20, 1925, p. 832, 4 figs. New jet arrangement for medium-capacity impulse wheel, designed by G. Gilkes & Co., and known as Turgo.

HYDRAULICS

Development of Science of. The Development of the Science of Hydraulics, E. P. Hamilton. Boston Soc. Civil Engrs.—Jl., vol. 12, no. 8, Oct. 1925, pp. 344–354, 4 figs. Résumé of early investigations; hydraulic measuring devices; modern developments of the science.

HYDROELECTRIC DEVELOPMENTS

California. Klamath River Plant Completed by the California Oregon Power Company. Jl. Electricity, vol. 55, no. 10, Nov. 15, 1925, pp. 364–371, 7 figs. Copco No. 2 hydraulic plant is 30,000-kva. development, and has largest wood-pipe line in the country; details of dam, intake structure, tunnels, wood-stave pipe, surge chamber, penstocks, power house, generating equipment and electric arrangements.

Canada. Some Economic Aspects of Hydro-electric Development in Canada. Contract Rec., vol. 39, no. 46, Nov. 18, 1925, pp. 1108–1110. Discussion answering questions: Has Canada unlimited water power? How soon will she require all of it? Would it be good business to allow export? Could exported power be recovered?

Gold and Silver Mines, Ontario. Hydro-Electric Development for Gold and Silver Mines in Northern Ontario, A. R. Webster. Ont. Dept. Mines, vol. 33, part 7, 1925, pp. 99–119, 20 figs. Power development of Northern Ontario Light & Power Co.; Northern Canada Power Co.; Great Northern Power Co.; Gowganda and South Bay companies; Canadian Associated Goldfields.

Italy. Hints on the Utilization of Water Power of Liro and Mera Rivers (Cenni sulla utilizzazione delle forze idrauliche del Torrente Liro e del Fiume Mera da parte della Societa Elettrica Interregionale Cisalpina), L. Gasparoni. Energia Elettrica, vol. 2, no. 9, Sept. 1925, pp. 829–847, 14 figs. Details of work planned and in course of execution by Elettrica Interregionale Cisalpina Co., including storage reservoirs, overdamming, canals, pressure conduits; head and tail races for turbines; equipment of plants includes Pelton wheels of 35,000 hp., 3-phase alternators of 30,000 kva. by Italian Brown-Boveri, 140,000-volt transmission lines.

New Brunswick, Canada. Generating Power in New Brunswick, S. R. Weston. Power House, vol. 18, no. 20, Oct. 20, 1925, pp. 70–73, 4 figs. Details of New Brunswick Elec. Power Commission's project at Grand Falls; few power developments offer an equal opportunity to industry, in so far as supply is concerned.

Northern Ontario, Canada. Power Development in Northern Ontario, A. R. Webster. Power House, vol. 18, no. 20, Oct. 20, 1925, pp. 73–75, 1 fig. Particulars of hydroelectric development in mining districts of northern Ontario which, with substantial increases in production looming, is of unusual interest.

Nova Scotia. Generating Power in Nova Scotia in 1925, H. A. Hatfield. Power House, vol. 18, no. 20, Oct. 20, 1925, pp. 76–77, 2 figs. Despite coal miners' strike in Nova Scotia in first half of 1925, interesting work was done at several power plants in province, and developments in hydroelectric field were quite extensive.

Saguenay River, Canada. Saguenay River De-

velopments from the Standpoint of Power, Pulp and Paper Electrometallurgy, L. E. Westman. Can. Chem. & Met., vol. 245–250, 6 figs. Review of what has been done and outline of what is in promise, from industrial standpoint.

HYDROELECTRIC PLANTS

Austria. The Lake Plan Plant in Austrian Tyrol (Das Planseewerk der Marktgemeinde Reutte in Tirol). Zeit. des Bayerischen Revisions-Vereins, vol. 29, no. 19, Oct. 15, 1925, pp. 207–210, 8 figs. Details of expansion work of plant at Reutte, Lake Plan, and plans for final utilization of Lake Plan; Francis helical turbine for average head of 100 m.; SS three-phase generators of 3400 kva., 8500 volts, 600 r.p.m., 50 cycles.

Bonnington Falls, Canada. Power Plant at Lower Bonnington Falls. Elec. News, vol. 33, no. 21, Nov. 1, 1925, pp. 37–39, 9 figs. First unit of ultimate group of three, each 20,000 hp., has been placed in operation.

Brazil. The Fagundes Hydro-Electric Installation, Brazil. Engineering, vol. 120, no. 3128, Dec. 11, 1925, pp. 735–737, 17 figs. partly on supp. plate. Concrete dam is 260 ft. long on top and 40 ft. high above normal river bed; water is led from dam by means of main pipe line to point above power house, where distributor feeds two penstocks, one for each turbine; turbines are of Francis spiral-case type with rotors overhung on ends of horizontal shafts.

British Columbia. Some Further Interesting Views of Stave Lake Power Plant. Elec. News, vol. 33, no. 22, Nov. 15, 1925, pp. 35–37, 7 figs. Shows phases of development work of Brit. Columbia Elec. Ry. Co.

Some Further Interesting Views of Stave Lake Power Plant. Contract Rec., vol. 39, no. 46, Nov. 18, 1925, pp. 1096–1098, 7 figs. Stave Lake total capacity now 87,500 hp.; Brit. Columbia Elec. Ry. Co. total for all plants 212,200 hp.

Stave Falls Power Development, W. G. Murrin. Power House, vol. 18, no. 20, Oct. 20, 1925, pp. 80–82, 3 figs. Plant has capacity of 87,500 hp.; Stave Lake has a storage capacity of 471,000 acre feet, and plant has an annual capacity of 250,000,000 kw-hr.

Scotland. A Fifeshire Hydro-Electric Undertaking. Elec. Rev., vol. 97, no. 2502, Nov. 6, 1925, pp. 741–743, 5 figs. Details of Balgonie Colliery Co.'s installation.

Spain. Electricity Supply of Spain (Die Elektrizitätsversorgung Spaniens), A. Martin Schmidt. Elektrotechnische Zeit., vol. 46, no. 47, Nov. 19, 1925, pp. 1765–1770, 13 figs. Reviews power-plant conditions in Spain based on personal visit; hydroelectric and thermoelectric plants; influence of American practice.

The Villalba Fall (Salto de Villalba), J. Làzaro Urra. Revista de Obras Publicas, vol. 73, no. 2441, Nov. 15, 1925, pp. 519–523, 12 figs. Discusses development of Villalba power station for additional electricity supply of Madrid, using waters of fall and of Júcar river, storage lake, canals, pressure conduits, etc.; electric equipment, alternators delivering current of 6000 volts to busbar which is stepped up by transformers to 60,000; line equipment being calculated for 85,000.

I

ICE MANUFACTURE

Engine-Room Costs. Engine Room Costs in Ice Making, J. H. Howell. Power House, vol. 18, no. 21, Nov. 5, 1925, pp. 20–21, 2 figs. Necessity of having accurate information on engine-room costs, in ice-making and cold-storage plants, is daily becoming more apparent, calculations on a theoretical basis being useless to operating engineer. Abstract of paper read before Pacific Coast Cold Storage Warehousemen's Assn.

IMPACT TESTING

Notched-Bar Tests. Field of Application of the Repeated Notched-Bar Test (Aus dem Anwendungsgebiet des Zweiproben-Kerbschlagversuches), M. Moser. Stahl u. Eisen, vol. 45, no. 46, Nov. 12, 1925, pp. 1879–1881, 3 figs. Investigates problem of influence of testing temperature, showing great influence on working speed and slight influence on working constants of testing temperature.

INDUSTRIAL MANAGEMENT

Budgetary Control. Budgetary Control in Industry, L. Perry-Keene. Indus. Mgmt. (Lond.), vol. 12, no. 11, Nov. 1925, pp. 517–519. Methods of control; cost accountant; definition of budgetary control; executive ability; cost of plant maintenance; etc.

Employer-Employee Relationship. Idea Employer-Employee Relationship, A. Hardgrave. Ice & Refrigeration, vol. 69, no. 6, Dec. 1925, pp. 335–338. Discussion of this subject contained in report of Industrial Relations Committee of Nat. Assn. of Ice Industries, presented at annual meeting in Los Angeles, Calif.; arguments for and against employee stock ownership; employees' wage agreement of large ice company.

Financial and Industrial Investigation. The Financial and Industrial Investigation, A. Andersen. Mgmt. & Admin., vol. 10, no. 6, Dec. 1925, pp. 325–328. Its purposes and problems; types and sources of information; points of analysis; conditions leading to internal investigation; difficulties of external investigation.

Flow-of-Work Regulation. Effecting Economies by Regulating Work Flow, A. Whitehead. Indus. Mgmt. (Lond.), vol. 12, nos. 3 and 9, Mar. and Sept. 1925, pp. 191–192 and 441–442, 1 fig. Factors which influence economy; how economies have been effected by eliminating losses arising from a poor or irregular flow of work.

Furniture Plants. Management in Southern Furniture Plants, Chas. F. Scribner. Mgmt. & Admin., vol. 10, nos. 4, 5, and 6, Oct., Nov. and Dec. 1925, pp. 217–220, 267–270, and 349–352, 7 figs. Oct.: Aroused executive interest as aid in effective production control; developing control methods; manufacturing orders and their handling; scheduling orders and following up. Nov.: Training employee; results from employment department; time-study operation analysis. Dec.: Cost finding.

Production Checking. A Policy That Catches Errors Before Production Begins, B. J. Dowd. Am. Mach., vol. 63, no. 25, Dec. 17, 1925, pp. 975–976, 3 figs. Checking, re-checking, and checking again as practiced in typewriting plant has made tool and product losses occasioned by mistakes practically negligible.

Production Control. An Effective Production Control System, J. J. Swan. Mgmt. & Admin., vol. 10, no. 6, Dec. 1925, pp. 317–320, 3 figs. Describes system employed in manufacture of automatic printing presses.

Production Control in the Newsprint Industry, Geo. D. Bearce. Am. Soc. Mech. Engrs.—advance paper, for mtg. Nov. 30–Dec. 4, 1925, 18 pp., 10 figs. Outlines manufacturing processes and production methods of majority of mills in North America making "standard" newsprint paper; describes general production controls used in groundwood, sulphite and paper departments; manufacturers have adopted standard methods of calculating 3 "operating reports" and 4 "conversion cost reports" covering important operations in pulp and paper departments; former are described in detail and illustrated by forms.

Purchasing. The Purchasing Department. Automobile Engr., vol. 15, nos. 207, 209 and 210, Oct., Nov., and Dec. 1925, pp. 321–322, 420–421 and 453–454, 3 figs. Outline of scheme that has proved satisfactory in practice.

Sales Program. How We Inject the Operating Point into the Sales Program, A. M. Williamson. Factory, vol. 35, no. 6, Dec. 1925, p. 899. By system in plant, in which author is superintendent, sales department is able to forecast with surprising accuracy demand for product several months in advance. (Abstract.) Paper before Poduction Executives Division, Am. Mgmt. Assn.

Successful. Successful Industrial Management, J. S. Gray. Machy. (N. Y.), vol. 32, no. 4, Dec. 1925, pp. 303–304. Lack of information as cause of much dissatisfaction; foreman's place in organization; encouraging loyalty and coöperation; all-important matter of wages; rules and regulations around factory; avoiding cost of labor turnover; importance of understudies; need of accurate records.

INSULATING MATERIALS, HEAT

Testing. Guaranties for Heat Insulation Material and Their Verification (Wärmeschutztechnische Garantien und ihre Nachprüfung), J. S. Camerer. Zeit. für die gesamte Kälte-Industrie, vol. 32, no. 11, Nov. 9, 1925, pp. 157–164, 9 figs. Discusses development of technical guaranties and examines methods of testing for acceptance generally used, showing that temperature drop in a hot or cold transmission line and so-called coefficient of heat saved are entirely unsuitable as criteria of quality and efficiency of material supplied; gives practical examples.

INTERNAL-COMBUSTION ENGINES

Brown Double-Expansion. A Double Expansion Internal Combustion Engine. Instn. of Engrs., Australia, vol. 2, no. 7, July 1925, pp. 38–44, 5 figs. Particulars of marine engine invented by W. Brown, of Sydney, Australia; weight of engines 1500 lb.; has one cylinder; bore $8^1/_2$ in., stroke 10 in., rated horsepower 10, 360 r.p.m.

Detonation. Present Status of the Facts and Theories of Detonation, G. L. Clark and W. C. Thee. Indus. & Eng. Chem., vol. 17, no. 12, Dec. 1925, pp. 1219–1226, 2 figs. Attempt is made to collect recent widely scattered and heretofore unrelated experimental, chemical, physical, and engineering facts bearing upon general phenomenon of detonation and factors affecting it, in order to subject theories to critical examination, to suggest further experiments of fundamental nature, and to make practical applications particularly to design and operation of internal-combustion engines. Bibliography.

Inlet-Stroke Pressures. Inlet Stroke Pressures Revealed by Indicator Tests, C. Z. Rosecrans. Automotive Industries, vol. 53, no. 26, Dec. 24, 1925, pp. 1053–1054, 3 figs. Determinations made at Univ. of Illinois show that absolute pressure at beginning of compression stroke varies from 6.5 lb. on low throttle to 13.9 lb. at low speed on nearly full throttle.

Maybach. Development of the Maybach Engine for Airships (Entwicklung der Maybach-Luftschiffmotoren), K. Beuerle. Luftfahrt, vol. 29, no. 20, Oct. 20, 1925, pp. 313–316, 5 figs. Details of development of design, reduction of fuel consumption, and of weight and space required, development of carburetor, increase of horsepower to 210, 240, 260, and 400, at 1400 r.p.m.

Romeiser. The Romeiser Two-Stroke Reaction Motor and Compressor (Der Romeiser Zweitakt-Reaktionsmotor mit Kompressor), Wirtschafts-Motor, vol. 7, no. 6, June 1925, pp. 1–7, 9 figs. Details of ballistic principle and design of engine with pistons, combustion in cylinder taking place purely adiabatically, all water or air cooling being dispensed with, energy hitherto taken up by cooling water being also converted into mechanical work; fuel consumption reduced to 50 per cent.

Swedish. Swedish Internal-Combustion Engines (Schwedische Verbrennungskraftmaschinen), E. Hubendick. Zeit. des Vereines deutscher Ingenieure, vol. 69, no. 45, Nov. 7, 1925, pp. 1403–1408, 22 figs. Description of engines now employed in Sweden; data on dimensions, working performance and characteristics in outboard, carburetor, hot-bulb, ignition-chamber, and Diesel engines.

[See also AIRPLANE ENGINES; AUTOMATIC ENGINES; DIESEL ENGINES; OIL ENGINES.]

IRON CASTINGS

Cleaning. Reducing the Cost of Cleaning Ferrous Castings, J. H. Hopp. Am. Metal Market—Monthly Rev. Section, vol. 32, no. 222, Nov. 17, 1925, pp. 14–15. Facing and molding sand character; fins; effects of gates and risers; composition of cores; cleaning-department factors; mills; sand blasting vs. milling; determining cleaning method; estimating costs; grinding; rubber bonded grinding wheels. Paper presented on behalf of Chicago Foundrymen's Club.

Defective. Defective Castings. Foundry Trade Jl., vol. 32, no. 482, Nov. 12, 1925, p. 408. Two chief causes are stated to be faults in metal itself, and bad molding and faulty pouring; prevention of such defects.

IRON, PIG

Merchant, Future of. The Future of Merchant Pig Iron, C. E. Wright. Iron Age, vol. 116, no. 25, Dec. 17, 1925, pp. 1657–1659, 3 figs. Points out that high freight rates, large imports of foreign iron and economic changes have put many furnaces on inactive list; by-product coke ovens considered as possible remedy.

L

LATHES

Single-Spindle. Single-Spindle Automatic. Machy., (Lond.), vol. 27, no. 687, Nov. 26, 1925, p. 278, 2 figs. Machine made by firm of Boehringer, Goeppingen, Germany, has single pulley drive and self-selecting speeds.

Turret, Operations on. Spherical Turret Lathe Operations, Chas. O. Herb. Machy. (N. Y.), vol. 32, no. 4, Dec. 1925, pp. 270–272, 9 figs. Turning and boring ball and socket surfaces on pillow block parts.

LIGHTING

Factories. Ways of Obtaining the Best Lighting, A. G. Anderson. Mgmt. & Admin., vol. 10, no. 6, Dec. 1925, pp. 345–348, 5 figs. How to plan factory illumination and upkeep of equipment.

LIQUID AIR

Plant Calculation. Calculation of Air Liquefaction Plants on the Basis of New Measurements of the Thomson-Joule Effect (Ueber die Berechnung von Luftverflüssigungsanlagen auf Grund neuer Messungen des Thomson-Joule-Effektes), H. Hausen. Zeit. für die desamte Kälte-Industrie, vol. 32, nos. 7 and 8, July and Aug. 1925, pp. 93–98 and 114–122, 16 figs. Calculation of diagrams of state for up to 200 atmos. and —175 deg. cent. on known thermodynamic relations; calculation of liquefaction plants from diagrams of state liquefaction by Linde process; liquefaction by Claude and Heylandt processes; comparison of the three processes.

LIQUIDS

Viscosity under Pressure. The Viscosity of Liquids under Pressure, P. W. Bridgman. Nat. Acad. Sciences—Proc., vol. 11, no. 10, Oct. 1925, pp. 603–606. Method developed by which relative viscosity of liquids may be determined over wide range of pressures at various temperatures.

LOCOMOTIVE BOILERS

Laying Out of. Laying Out Locomotive Boilers, W. E. Joynes. Boiler Maker, vol. 24, nos. 1, 2, 3, 4, 5, 6, 8, 9, 10, 11, and 12, Jan., Feb., Mar., Apr., May, June, Aug., Sept., Oct., Nov., and Dec. 1925, pp. 1–5, 40–44, 72–75, 99–102, and 108, 129–134, 166–168, and 170, 235–238, 261–267, 292–296, 324–326, and 350–351, 49 figs. Jan.: Longitudinal seams; firebox design; plates; development of one-piece crown and side sheets. Feb.: Development of backhead and roof sheet of boiler. Mar.: Method of finding outline of one-piece crown and side sheet. Apr.: Spacing of rivets; outline of one-piece roof and side sheet; locating radial stays and staybolts on roof sheet. May: Practical suggestions to follow in boiler development; triangulation development of one-piece crown and side sheets and three-piece roof and sides. June: Combustion-chamber development; radial stays and staybolts; roof-sheet development. Aug.: Flanged-sheet development; backhead and firebox back sheet; tapering flange radius. Sept.: Firebox tube, inside throat, outside throat and front tube-sheet plate developments. Oct.: Finding developed size of plain ring course, laying out dome course. Nov.: Smokebox-shell development, laying out fire-holes; method of locating flexible staybolts. Dec.: Tapering backhead and firebox back-sheet flange radii; arch tubes.

Staybolt Inspection. Inspection of Locomotive Water Space Flexible Stay Bolts, E. S. Fitzsimmons. South. & Southwest. Ry. Club, vol. 18, no. 5, Sept. 1925, 17 pp. between pp. 8 and 40 and (discussion) 12 pp. between pp. 40 and 60, 18 figs.; also (abstract) in Ry. Age, vol. 79, no. 22, Nov. 28, 1925, pp. 989–990, 1 fig.; and Ry. Rev., vol. 77, no. 23, Dec. 5, 1925, pp. 844–847. Describes method and device which obviates necessity of removing caps from flexible staybolts for periodic inspection; explanation of development of flexible bolt and methods of testing.

LOCOMOTIVES

Articulated. Articulated Locomotive Tests in

India and Burma. Ry. Engr., vol. 46, no. 550, Nov. 1925, pp. 399–403, 7 figs. Tests between meter-gage Garratt and Mallet locomotives on Burma Railways have given interesting results.

Coaling Plants. Coal and Sand Facilities Embody Novel Features. Ry. Age, vol. 79, no. 22, Nov. 28, 1925, pp. 982–983, 5 figs. Santa Fe is now using new stations of unique design at Argentine, Kan., and Shopton, Ia.

Development in Switzerland. Development of Steam Locomotive in Switzerland (Zur Entwicklung der Dampflokomotive in der Schweiz), G. Zindel. Schweizerische Bauzeitung, vol. 86, no. 13, Sept. 26, 1925, pp. 154–165, 22 figs. Particulars regarding locomotives from 1847 to 1917, when last steam locomotive with five driving axles was delivered to Federal Railways, which was soon followed by electric locomotive with six driving axles.

Electric. See ELECTRIC LOCOMOTIVES.

Lehigh-Valley-Railroad, Development of. The Motive Power of the Lehigh Valley Railroad, P. T. Warner. Baldwin Locomotives, vol. 4, no. 2, Oct. 1925, pp. 14–36, 59 figs. Development from 1896 to present time; weights and dimensions of locomotives now in service, as given in paper, conform to official records of Railroad Co.

Lima 2-8-4. The 2-8-4 Lima Locomotive. Cent. Ry. Club of Buffalo, N. Y.—Official Proc., vol. 33, no. 4, Sept. 1925, pp. 1867–1878 and (discussion) 1879–1880, 11 figs. Practical tests prove it has 30 per cent increased operating capacity; features of construction; improved design of cylinders and high steam pressure giving great horsepower output backed up with boiler producing greater energy.

Mechanical Features. Ideas and Suggestions for Future Locomotive Development, Wm. A. Newman. Boiler Maker, vol. 24, no. 12, Dec. 1925, pp. 337–341, 3 figs. General outline of mechanical features of proposed steam locomotive with special reference to boiler details.

Narrow-Gage. Series Construction of Narrow-Gage Locomotives (Ueber Reihenbildung im Bau von Nebenbahnlokomotiven), D. R. P. Wagner. Verkehrstechnik, vol. 42, no. 39a, Sept. 1925, pp. 748–755, 6 figs. Advantages to producer and consumer in series manufacture; interchangeability of parts in products originating in different factories; reduction of multiplicity of parts by formation of series; description of series of types of German Railway, including shunting and narrow-gage types C., D., 1C1, 1C, 1D1; tabulation of their principal interchangeable parts.

Performance. Locomotive Performance, Train Load and Time of Journey (Lokomotivleistung, Zuglast und Fahrzeit), G. Pfaff. Organ für die Fortschritte des Eisenbahnwesens, vol. 80, no. 16, Aug. 30, 1925, pp. 313–318, 7 figs. Discusses determination of minimum time for journeys by various methods, also for sections only, and gives examples.

Santa Fe Type. Santa Fe Type Locomotives for Atlantic Coast Line. Ry. Age, vol. 79, no. 22, Nov. 28, 1925, pp. 1001–1002, 1 fig. Develop tractive force of 75,700 lb., with 30-in. by 32-in. cylinders, 63-in. diam. drivers and 195-lb. steam pressure.

Steam-Turbine. Steam Turbine Locomotives, C. S. Darling. Ry. Engr., vol. 46, no. 551, Dec. 1925, pp. 435–439, 1 fig. Consideration of problems involved in design of efficient steam-turbine locomotive.

Whistles. A Study of Locomotive Whistles, A. L. Foley. Ry. Age, vol. 79, no. 23, Dec. 5, 1925, pp. 1043–1047, 7 figs. Points out that more effective warnings can be obtained when whistle is located in front of stack.

LUBRICATING OILS

Researches. Laboratory Researches on Mineral and Lubricating Oils (Le ricerche di Laboratorio sugli olii minerali e di lubrificazione), C. A. Bertella. Ingegneria, vol. 3, no. 12, Dec. 1, 1924, and vol. 4, no. 8, Aug. 1925, pp. 408–415 and 283–291, 40 figs. Discusses tests as to acidity, viscosity, and other physical properties, calorimetry, temperature of combustion, flashpoint, chemical properties; behavior of oil in contact with metal; lubricating power of oil; etc.

LUBRICATION

Journal. A Graphical Study of Journal Lubrication (Part III), H. A. S. Howarth. Am. Soc. Mech. Engrs.—advance paper, for mtg. Nov. 30–Dec. 4, 1925, 23 pp., 48 figs. Continuation of investigation reported to Society under same title in 1923 and 1924; friction curves are presented for central and offset bearings whose curvature radius exceeds that of journal; characteristics of fitted partial bearings are then studied, including their carrying capacities and friction.

M

MACHINE TOOLS

Built-In Motors. Machines with Built-In Motors, D. K. Frost. Am. Mach., vol. 63, no. 22, Nov. 26, 1925, pp. 837–839, 7 figs. Outline of what has been accomplished in building motors into machines for various kinds of work; use of belts or chains is likely to continue as connecting link between motor and spindle for many classes of machine.

Crankpin-Turning Machine. Richards Crank Pin Turning Machine. British Machine Tool Eng., vol. 3, no. 35, Sept.-Oct. 1925, pp. 322–326, 6 figs. Describes Richards patent crankpin turning machine, together with sequence of operations on a typical crank and examples of cranks produced.

Design. Elements of Machine Tools (Ueber Konstruktionselemente an Werkzeugmaschinen), S. Weil. Maschinenbau, vol. 4, no. 21, Oct. 15, 1925, pp. 1027–1034, 28 figs. On basis of Leeuw's article in Am. Mach., Feb. 7, 1925, "Methods of Machine Tool Design," discusses design and wear of guides, bed-plate construction for lathes, general rules for construction of lathes, adjustability of guides, requirements of slide rests, bearing, and adjustability of screws, etc.

Punching-Slotting Machines. The "Butler" Puncher Slotter. British Machine Tool Eng., vol. 3, no. 34, July-Aug. 1925, pp. 290–292, 3 figs. Heavy costs of forging or stamping many large pieces used in locomotive and car building and in fact in almost every branch of engineering trade, may be now enormously reduced by use of Puncher Slotting Machines; puncher slotters will remove steel of good quality at rate of $^4/_5$ lb. per min.; suitable for all kinds of slotting and shaping work within their capacity, and by reason of their extreme rigidity, work produced is of exceptional finish and accuracy.

Railway Shops. Some New Machine Tools at North Road Works, Darlington, London & North Eastern Railway. Ry. Engr., vol. 46, nos. 550 and 551, Nov. and Dec. 1925, pp. 392–398 and 425–430, 20 figs. Deals with developments at Company's locomotive works at Darlington; describes vertical drilling and boring machine, slot drilling machine, machine for manufacture of staybolts, etc.

MACHINERY

Age Determination. Determination of Coefficient of Age (Sulla determinazione del coefficiente di vetustà), N. Famularo. Ingegneria, vol. 4, no. 8, Aug. 1925, pp. 292–297, 5 figs. Develops a method for mathematical estimation of age from useful life of machinery, its value as scrap, and interest on capital inverted in it.

MALLEABLE CASTINGS

Black-Heart Process. Malleable Iron Castings, R. Micks. Can. Foundryman, vol. 16, no. 11, Nov. 1925, pp. 11–13. Points out that of the two processes of manufacturing malleable iron castings, black heart, or American process, produces better malleable iron in shorter time and with less expense.

MATERIALS HANDLING

Accident Prevention. Safety in Materials Handling, D. S. Beyer. Am. Soc. Mech. Engrs.—advance paper, for mtg. Nov. 30–Dec. 4, 1925, 30 pp., 15 figs.; also (abstract) in Am. Mach., vol. 63, no. 23, Dec. 3, 1925, pp. 890–891. After demonstrating seriousness of materials-handling accident hazard, author computes yearly economic loss to be $250,000,000; analyzes such accident hazards in general broad classifications and points out few methods of prevention; calls attention to necessity for including in construction drawings and specifications means for prevention of such accidents.

Hidden Costs. The Hidden Costs in Handling Bulk Materials. Factory, vol. 35, no. 6, Dec. 1925, pp. 896–899, 966, 968, and 970, 972, 974, 976 and 978, 6 figs. Contains following contributions: Handling Coal and Ashes Is a Simple Matter Now, C. H. Kirkpatrick; Conveyors Pave the Way to Lower Handling Costs, E. T. Cristiani; A Monorail Conveyor Cut Our Handling Costs 29%, H. H. MaComber; $7,805.47 Saved Annually by Improved Handling Methods, F. A. Ory.

Mass-Production Plant. Material Handling Methods in the Edward G. Budd Plant, W. A. Graf. Mgmt. & Admin., vol. 10, no. 6, Dec. 1925, pp. 321–324, 6 figs. Materials-handling methods and equipment employed by largest plant in world engaged in manufacture of all-steel open and closed bodies for automobiles and other stamped-metal products.

MEASURING INSTRUMENTS

High Speed by Sound Vibration. Measuring High Speed by Sound Vibration, C. R. Alden. Machy. (N. Y.), vol. 32, no. 4, Dec. 1925, pp. 286–288, 3 figs. Device invented by author is arranged so that pitch of sound emitted by high-speed spindle is compared with sound or note emitted by speed-measuring device; latter is so calibrated that it indicates directly revolutions per minute corresponding to given note in musical scale, which, in turn, is equivalent to certain number of vibrations per second.

Internal-Diameter Measurement. The Measurement of Internal Diameter, H. T. Wright. Machy. (N. Y.), vol. 32, no. 4, Dec. 1925, pp. 213–214, 5 figs. Describes machine designed and set up by writer in 1924, consisting essentially of bell-crank lever, one virtual arm of which was vertical, and carried measuring rod, other being horizontal and set to give contact with knife edge of tilting mirror arrangement.

MECHANISMS

Geneva Movement. Some Characteristics of the Geneva Movement, B. M. Fine. Am. Mach., vol. 63, no. 23, Dec. 3, 1925, pp. 913–915, 4 figs. Discusses analysis previously published and gives his views, mathematically supported and graphically illustrated.

METALS

Corrosion. Wear and Corrosion in Metal Work (L'usure et la corrosion dans les ouvrages métalliques), J. Jacquart. Annales des Ponts et Chaussées, vol. 95, no. 4, July-Aug. 1925, pp. 5–66, 13 figs. Theory of corrosion, sublimation and dissolution of metal; chemical action, precipitation of ions, galvanic action, electrolytic action, theory of stray currents; wear of ferrous metals, oxidation and rust formation, errosion; non-ferrous metals, protection of metals, coatings, etc.

Fatigue of. High-Frequency Fatigue Tests, C. F. Jenkin. Roy. Soc.—Proc., vol. 109, no. A749, Sept. 1, 1925, pp. 119–143, 8 figs. Experiments on high-frequency fatigue in copper, Armco iron, and mild steel carried out in Engineering Laboratory, Oxford, for Fatigue Panel of Aeronautical Research Committee; results show that mechanism of fatigue requires time.

MILLING CUTTERS

Sizes of Standard. Sizes of Standard Milling Cutters (Simplified Practice). Am. Mach., vol. 63, no. 23, Dec. 3, 1925, p. 907. Reference book sheet.

Standardization. Standardizing Milling Cutters, T. R. Jones. Am. Mach., vol. 63, no. 23, Dec. 3, 1925, p. 916, 1 fig. Revised design of shell-end mills; suggests that still further simplification of end mills can be had by adopting uniform design.

MILLING MACHINES

Dividing Heads. Dividing Head Designed for Heavy Work, O. S. Marshall. Machy. (N. Y.), vol. 32, no. 4, Dec. 1925, pp. 305–306, 3 figs. New type of dividing head designed to cover wider range of precision indexing and to handle heavier work than ordinary type.

MOLDING METHODS

Cast-Iron Pistons. Pistons for Internal Combustion Engines, A. J. Richman and J. L. Francis. Metal Industry (Lond.), vol. 27, nos. 17, 19, and 21, Oct. 23, Nov. 6 and 20, 1925, pp. 389–390, 437–438 and 489–491, 16 figs. Authors describe what they have found to be best molding and metallurgical practice in production of cast-iron pistons of various types; molding and allied processes for pistons of small gasoline and paraffin engines are first considered; followed by discussion of larger-type pistons and also chief metallurgical problems involved.

Dry-Sand. Dry-Sand Moulding, C. H. Brown. Foundry Trade Jl., vol. 32, no. 482, Nov. 12, 1925, pp. 415–416 (including discussion). Milling of sand; ramming a dry-sand mold; venting; effects of bat gating; loam cores.

MOLDS

Permanent. Production of Castings in Permanent Moulds. Brit. Cast Iron Research Assn.—Bul., no. 10, Oct. 1925, pp. 9–10. Bibliography covering more important papers and patent specifications since 1911 dealing with production of castings in permanent molds.

MOTOR BUSES

Development. Motor 'Bus Developments. Motor Transport (Lond.), vol. 41, no. 1081, Nov. 16, 1925, pp. 665–666. A survey of conditions responsible for production of present-day light, high-speed public service vehicles. Résumé of paper read by L. G. Wyndham Shire at C. M. U. A. Road Traffic Conference, Nov. 5, 1925.

Engines. The Prospects of the Six-cylinder Engine, E. Reeve. Motor Transport (Lond.), vol. 41, no. 1083, Nov. 30, 1925, pp. 711–713, 7 figs. Advantages of 6-cylinders for commercial vehicles, particularly for passenger carrying.

Six-Wheel. Six-Wheel Motorcoach Operation, W. F. Evans. Soc. Automotive Engrs.—Jl., vol. 17, no. 6, Dec. 1925, pp. 620–621, 1 fig. Detroit Motorbus Co. has been operating fleet of 6-wheel motor coaches for period of 12 or 13 months, and their experience leads them to believe that this type has before it a tremendous future, not only for passenger transportation, but for heavier truck loads.

MOTOR-TRUCK TRANSPORTATION

Coördination of Railroad and. Coördination of Railroad and Motor Truck in Freight Handling, Jos. L. Scott. Soc. Automotive Engrs.—Jl., vol. 17, no. 6, Dec. 1925, pp. 607–608, 2 figs. From observations and experiences, it is believed that economic haul for motor truck is from 50 to 75 miles a day, that further coördination between railroad systems and motor-trucking companies will occur, and that all motor vehicles engaged in common-carrier service should come under state or federal regulation.

MOTOR TRUCKS

British Show, Olympia. The English Truck Show, M. W. Bourdon. Automotive Industries, vol. 53, no. 23, Dec. 3, 1925, pp. 936–939, 11 figs. Buses are center of attraction at Olympia show; 68 makes of vehicles, including 11 American, shown; features of exhibit, among which are: increase in number of bus models with forward driving position; wider use of pneumatic tires for trucks and buses; tendency for enclosed bus to displace open type; trend of demand in truck field for vehicles of smaller load capacity.

The Commercial Motor Transport Exhibition. Automobile Engr., vol. 15, no. 210, Dec. 1925, pp. 445–452, 25 figs. Description of exhibits at Olympia Exhibitions.

Four-Wheel-Drive. New Four-Wheel Drive Truck Proves Satisfactory in Army Tests, P. M. Heldt. Automotive Industries, vol. 53, no. 24, Dec. 10, 1925, pp. 972–974, 4 figs. Vehicle built for service in rough terrain consists largely of stock parts; has novel front drive and low gear of very large ratio; steers easily; product of Coleman Motors Corp.

MOTORCYCLES

Cleveland 4-Cylinder. Four-Cylinder Model Added to Cleveland Motorcycle Line. Automotive Industries, vol. 53, no. 23, Dec. 3, 1925, p. 943, 1 fig. Engine is high-speed, 4-cycle, direct air-cooled type; crankcase is of cast aluminum.

MUSEUMS

Science. The Science Museum, South Kensington. Nature (Lond.), vol. 116, no. 2920, Oct. 17, 1925, pp. 580–583, 4 figs. Plan of museum buildings and arrangement of collections.

N

NICKEL STEEL

Impact Values. Impact Values of a Nickel Steel, F. T. Sisco. Iron Age, vol. 116, no. 23, Dec. 3, 1925,

pp. 1513–1514, 2 figs. Effect of quenching and drawing temperatures on Izod results. Published by permission of Chief of Air Service, U. S. War Dept.

Machinery. Nickel Steels in Machinery, J. W. Urquhart. Mech. World, vol. 78, no. 2028, Nov. 13, 1925, pp. 383–384. Machining qualities of nickel steel; case-carburizing qualities; primal cause of nickel-steel strength; finer "grain" in nickel steels; outstanding advantage; simplified heat treatment.

O

OIL ENGINES

Industrial Plants. Some Uses for Oil Engines. Power, vol. 62, no. 22, Dec. 1, 1925, pp. 840–841, 5 figs. Suitability of oil engines for oil plants needing process hot water; comparative operating expenses and first costs of Diesels and steam engines.

Plenty-Still. The Plenty-Still Oil Engine. Mar. Eng. & Motorship Bldr., vol. 48, no. 578, Nov. 1925, p. 397, 1 fig. Preliminary particulars of latest adaptation of Still principle in engine undergoing tests at Newbury; single-cylinder heavy-oil engine intended to be applied to trawlers.

OIL FUEL

Centrifuges for Purifying. Centrifuges for Diesel Fuel (Zur Reinigung der schweren Brennöle durch Zentrifugen), H. Wittmaack. Wirtschaftsmotor, vol. 7, no. 8, Aug. 1925, pp. 11–13. It has been found that Diesel fuel oils of 24 to 36 deg. B. gravity can be used without disadvantage in Diesel engine after ordinary filtration; impurities can be centrifuged out especially if fuel oil is heated; centrifuges involving gas-proof containers have been developed and heavier fuels should be treated in these.

Economical Application. Research in Liquid Fuel Economy, M. Sklovsky. Am. Iron & Steel Inst.—advance paper, for mtg. Oct. 23, 1925, 19 pp., 11 figs.; also (abstract) in Fuels & Furnaces, vol. 3, no. 11, Nov. 1925, pp. 1247–1252, 4 figs. Discussion is limited to application of liquid fuel to metallurgical operations in industrial production furnaces; points out that three distinct directions of effort may be applied for obtaining better fuel economy: (1) by proper combustion efforts; (2) by better furnace adaptation and construction; (3) by better attention to furnace.

OXYACETYLENE CUTTING

Metals. Advancement in the Gas Cutting of Metals, A. S. Kinsey. Am. Welding Soc.—Jl., vol. 4, no. 9, Sept. 1925, pp. 20–22. Tests show that there is saving of from 10 to 20 per cent in oxygen consumption, and equivalent saving in time when purity of oxygen is increased from 99 to 99.5 per cent.

Steel Foundry. Steel Industry Uses Acetylene Gas to Advantage. Iron Trade Rev., vol. 77, no. 22, Nov. 26, 1925, pp. 1345–1346. Review of paper read before Int. Acetylene Assn., by R. W. Thomas, on influence of oxyacetylene cutting on steel-foundry practice.

OXYACETYLENE WELDING

Bronze Welding of Locomotive Cylinders. Bronze Welding of Locomotive Cylinders. Acetylene Jl., vol. 27, no. 4, Oct. 1925, pp. 174–176, 7 figs. Describes operation in welding broken parts of locomotive after collision; advantages of bronze welding over welding with cast iron or steel rods.

Piping, Power-Plant. Gas Welding of Power Plant Piping in Shop and Field, A. W. Moulder. Am. Welding Soc.—Jl., vol. 4, no. 10, Oct. 1925, pp. 5–23, 15 figs.; also (abstract) in Welding Engr., vol. 10, no. 11, Nov. 1925, pp. 40–45, 10 figs. Outlines factors involved in problem of welding workmanship, including materials, tools, methods, and instruction and tests.

Gas Welded Power Line, Geo. F. Walker. Welding Engr., vol. 10, no. 10, Oct. 1925, pp. 19–20, 6 figs. Welded 8-in. steam pipes designed to carry over 200-lb. pressure.

Torches and Regulators, Standardization of. Standardization of Hose Connections for Welding and Cutting Torches and Regulators. Boiler Maker, vol. 24, no. 12, Dec. 1925, pp. 342–343, 2 figs. Gives list of standard and optional requirements.

P

PACKING

Safe. Ways to Pack Safely, W. S. Knight. Factory, vol. 35, no. 5, Nov. 1925, pp. 736–738, 752, and 754, 15 figs. Methods learned from 1,000,000 shipments a year; basic principles for safeguarding products in transit, developed by Gen. Elec. Co., Schenectady, N. Y.

PATTERNS

Aluminum-Painted. Protecting Patterns with Paints, J. D. Edwards and R. I. Wray. Iron Age, vol. 116, no. 24, Dec. 10, 1925, p. 1588. Advantages of aluminum paint recently developed by Aluminum Co. of Am.; various mixtures compared; savings claimed by their use; appreciable advantage is ease with which patterns may be withdrawn from mold.

PIPE

Bends. Notes on the Expansion of Pipe Bends, Wm. Chas. Rowe. Commonwealth Engr., vol. 12, no. 22, July 1, 1925, pp. 449–450, 4 figs. Gives results of tests of bent and straight pipes; according to Kent, no thorough attempt has been made to determine maximum amount of expansion which a U-loop or quarter bend would take up in a straight run of pipe having both ends anchored; graphs of tests given; states that it is desirable to make bend pipes of as reasonably large radius as is practicable and not to depend upon length of straight pipe, which transfers an enormous load to flanges. Paper read before Victorian Inst. of Engrs.

Welding. 17 Years' Experience in Pipe Welding, H. A. Woodworth. Heat. & Vent. Mag., vol. 22, no. 11, Nov. 1925, pp. 52–53 and 66–67, 2 figs. Some of the points learned from long practice; what to do and what to avoid in using welding process.

PLASTICITY

Study of. Plasticity, E. C. Bingham. Jl. Phys. Chem., vol. 29, no. 10, Oct. 1925, pp. 1201–1204, 2 figs. Discusses important properties in plastic flow which are recognized in connection with glue, rubber, paint, steel, etc.

PLATES

Stresses around Rectangular Openings. The Effect of the Radius of the Fillets on the Stresses around Rectangular Openings in Plates, T. H. Frost, P. E. Pihl and O. D. Colvin. Soc. Nav. Architects & Mar. Engrs.—advance paper, no. 2, for mtg. Nov. 12–13, 1925, 4 pp., 6 supp. plates. Outline of investigation, objects of which was to experimentally determine relation which exists: (1) between stresses at various points on corners of square openings in flat plate and ratio of width of plate to width of opening, and (2) between stresses at these points and radius of curvature of fillet at corners. See (abstract) in Mar. Eng. & Shipg. Age, vol. 30, no. 12, Dec. 1925, pp. 690–691, 1 fig.

POLISHING

Methods. Metal Polishing Methods. Machy. (N. Y.), vol. 32, no. 4, Dec. 1925, pp. 307–309. Operations for obtaining high luster; polishing operations for cutlery; changing direction of stroke necessary for good finish; importance of wheel densities; wheel speeds; speeds for buffing; abrasive friction or cutting power; wheels for surfaces not easily accessible; polishing non-ferrous metals; buffing methods.

POWER

Industrial Location, Effect on. Power—and the Industrial Map, J. A. Piquet. Indus. Mgmt. (N. Y.), vol. 70, no. 6, Dec. 1925, pp. 355–361, 7 figs. How power development is changing, not only industrial location, but whole structure of industrial production.

Waste Elimination in Generation and Transmission. Spotting and Stopping the Wastes in Power Generation, Transmission and Application. Indus. Mgmt. (N. Y.), Supp. Plate, vol. 70, no. 6, Dec. 1925. Chart as noted by F. Juraschek and visualized by F. H. Peard.

POWER GENERATION

Dairy Plants. Power Problems of the Dairy Industry, H. G. Skinner. Power House, vol. 18, no. 21, Nov. 5, 1925, pp. 17–18. Emphasizes need for economy in prevailing methods of heating, cooling, and refrigerating products of dairy industry.

Great Britain. Power Generation in Great Britain, D. Brownlie. Power House, vol. 18, no. 20, Oct. 20, 1925, pp. 78–79. Reviews developments in 1925 in steam and power generation field of United Kingdom.

POWER TRANSMISSION

Lubrication in. Reducing the Friction Tax on Power Transmission, A. F. Brewer. Indus. Mgmt. (N. Y.), vol. 70, no. 6, Dec. 1925, pp. 370–375, 11 figs. Modern lubrication and cost of power.

Mechanical, Control of. The Control of Mechanical Power Transmission, Wm. Staniar. Indus. Mgmt. (N. Y.), vol. 70, nos. 3, 4, 5, and 6, Sept., Oct., Nov., and Dec. 1925, pp. 135–140, 7 figs.; 218–222, 5 figs.; 272–276, 4 figs.; 338–343, 9 figs. Discusses means of increasing profits through proper belting and transmission installation and control. Sept.: Average methods which involve tremendous waste. Oct.: Direct influence of correct belting on profits. Nov.: Belting standardization. Dec.: Transmission applications.

Rope Drive. Rope Drives, P. W. Pell. Colliery Eng., vol. 2, no. 21, Nov. 1925, pp. 519–520, 2 figs. Merits and weaknesses; relative merits of manilla and cotton; factors influencing efficiency and long life; systems compared; over-roping.

PRESSWORK

Tools. Press Tools on a Production Basis, W. E. Irish. Am. Mach., vol. 63, nos. 22, 24, and 25, Nov. 26, Dec. 10 and 17, 1925, pp. 847–851, 925–928 and 969–973, 20 figs. Nov. 26: Equipment and facilities for toolmaking in modern pressed-steel plant; layout of department; standardization of parts; work distribution; points of design. Dec. 10: Press-tool organization; procedure in tool building, tryout and maintenance; efficiency department; records kept on tool performance. Dec. 17: Facilities for storing and handling press tools; method for identification; control of small hand tools through local cribs from central station; hand-tool construction, maintenance and salvage.

PULLEYS

Belt. Tests on Air Friction on Belt Pulleys (Versuche über die Luftreibung an Riemenscheiben), H. Cranz. Maschinenbau, vol. 4, no. 19, Sept. 17, 1925, pp. 927–931, 6 figs. Describes method followed in experiments; concludes that at usual velocities of about 25 m. per sec. losses due to air friction are exceedingly small but with further increase in velocity they increase rapidly.

PULVERIZED COAL

Boiler Firing. Pulverized Fuel for Boilers and Furnaces, W. R. Chapman. Fuel, vol. 4, nos. 8, 9, 10, and 11, Aug., Sept., Oct. and Nov. 1925, pp. 340–343, 396–400, 420–424 and 486–492. Aug.: Drying coal; pulverization; transport of powdered fuel; feeders, mixers and burners; combustion chamber. Sept.: Combustion-chamber lining; disposal of ash; suitability of fuels. Oct.: Efficiency; comparison with other methods of firing. Nov.: Includes summary of principal points in these articles.

Combustion. Length of Visible Flame and Length of Flame Travel in Combustion of Powdered Coal, H. Kreisinger. Indus. & Eng. Chem., vol. 17, no. 12, Dec. 1925, pp. 1232–1233. Length of flame is generally understood to be length of visible flame in furnace; visible flame is produced by combustion of volatile matter of coal; combustion of gaseous combustible is made visible by presence of small particles of incandescent carbon formed by breaking down of heavy hydrocarbons.

Conveying. Coal Dust Conveying (Kohlenstaubförderung), Walther. Braunkohle, vol. 24, no. 26, Sept. 26, 1925, pp. 599–601. Deals with mixing dust with air or gas ($^1/_{10}$ to $^1/_{25}$), for better conveying, and using compressed air for conveying from railway cars and bunkers.

Plants. Powdered Coal Installation at The Baldwin Locomotive Works, C. C. Bailey. Baldwin Locomotives, vol. 4, no. 2, Oct. 1925, pp. 37–46, 13 figs. Description of installation which comprises a main station with seven auxiliary or substations handling full requirements of 160 furnaces, 4 Babcock & Wilcox boilers of 600 hp. each, and 3 pile heating furnaces; main station, wherein is housed equipment necessary for crushing, drying, pulverizing, and ejecting coal to substations, has maximum capacity of 10 tons per hour.

Pulverized Coal in the Industrial Plant. Power, vol. 62, no. 22, Dec. 1, 1925, pp. 842–843, 6 figs. Points out advantages of unit system of firing.

PUMPING STATIONS

Diesel. Diesel Pumping Station, Portage, Wis. Power, vol. 62, no. 24, Dec. 15, 1925, pp. 924–926, 5 figs. Oil-engine plant shows estimated annual saving of $3362 over purchased electric power at prevailing rates and gasoline engine standby; when earnings have paid for plant, annual saving will exceed $7000.

PUMPS

Gasoline. The Shell Kerbside Petrol Pump. Engineering, vol. 120, no. 3128, Dec. 11, 1925, pp. 752–754, 3 figs. Describes improved design of pump constructed to design of Shell-Mex, Ltd.; in this type required quantity of fuel is delivered from actual measuring vessel, which is in full view of customer.

Troubles and Their Detection. What To Do When the Pump Stops, Wm. S. Jones. Power, vol. 62, no. 25, Dec. 22, 1925, pp. 966–968, 3 figs. Common causes of failure of direct-acting pumps; how to put pump back into service.

Turbo, Development of. Development of the Steam Turbo-pump as a Water Works Machine (Die Entwicklung der Dampfturbopumpe als Wasserwerksmaschine), B. Rosenfeld. Gas- u. Wasserfach, vol. 68, no. 41, Oct. 10, 1925, pp. 639–644, 9 figs. Discusses its development from coaling water pump of steam turbine plants and describes the various stages of this development.

PUMPS, CENTRIFUGAL

Boiler Feed Plant. Centrifugal Pumps as Feed Apparatus for High-Pressure Boiler Plants, G. Weyland. Eng. Progress, vol. 6, no. 11, Nov. 1925, pp. 353–354, 4 figs. Discusses use of centrifugal pumps as feed pump for high-pressure plants.

Gland Seals for. Improvement in Gland Seals for Centrifugal Pumps, J. C. Hobbs. Power, vol. 62, no. 24, Dec. 15, 1925, pp. 935–936, 3 figs. Notes on operating characteristics and proper way to seal shaft bearings from leakage.

R

RAILS

French Specifications. French Rail Specification. Engineering, vol. 120, no. 3124, Nov. 13, 1925, p. 601. Rail specification applicable to all railway systems of country is in force in France following earlier standardization of rail sections.

RAILWAY ELECTRIFICATION

France. Main Line Railway Electrification, P. Dawson and S. Parker Smith. Engineer, vol. 140, nos. 3640 and 3643, Oct. 2 and 23, 1925, pp. 341–344 and 423–426, 11 figs. Electrification in France. Oct. 2: Historical: reasons for electrification; choice of system; Paris-Orleans railway. Oct. 9: Paris-Lyons-Mediterranean Ry.; electrification on lines in neighborhood of Nice; results of electrification.

Southern Railway, England. The World's Greatest Suburban Electrification. Ry. Engr., vol. 46, nos. 550 and 551, Nov. and Dec. 1925, pp. 383–391 and 398, and 413–424, 35 figs. Technical details of Southern Ry.'s electrified service.

RAILWAY MANAGEMENT

Simplification of Operation. A Plan to Simplify Railroading, T. C. Powell. Ry. Rev., vol. 77, no. 21, Nov. 21, 1925, pp. 768–770. Pooling of trains, unification of terminals, extensive use of automotive facilities suggested. (Abstract.) Address delivered before West. Ry. Club.

RAILWAY MOTOR CARS

Diesel-Electric. Diesel Electric Cars, Canadian National Railway. Can. Ry. & Mar. Wld., no. 332,

Oct. 1925, pp. 501–503, 5 figs. Particulars of articulated oil-electric cars equipped with Diesel engines, and 60-ft. oil-electric cars also equipped with Diesel engines, being built at Montreal shops of Can. Nat. Ry.

Gasoline. Self Propelled Cars on Steam Railways. Ca. Ry. & Mar. Wld., no. 330, Aug. 1925, p. 388, 1 fig. Describes new Brill model gasoline cars of Can. Nat. Ry.; overall length 43 ft. $5\frac{5}{16}$ in., length over end sills 42 ft. $7\frac{5}{16}$ in., width over side sills $8\frac{1}{2}$ ft., extreme height 10 ft. $5\frac{1}{16}$ in., gasoline engine is of 4-cylinder 4-cycle type with $4\frac{3}{4}$-in. bore by 6-in. stroke, with a 3-in. crankshaft carried on 3 main bearings.

Types. Modern Railway Motor Cars (Sulle Automotrici Ferroviarie moderne), U. Baldini. Rivista Technica delle Ferrovie Italiane, vol. 28, no. 3, Sept. 15, 1925, pp. 98–115, 1 fig. Discusses steam, electric, storage-battery and internal-combustion-engine drives; speed changes, control, suspensions; economic questions; use for main-line traffic and for lines of little traffic.

RAILWAY REPAIR SHOPS

Accounting. Accounting in Railway Repair Shops (Betriebswirtschaftliche Vollabrechnung in den Eisenbahnausbesserungswerken), Stinner. Glasers Annalen, vol. 97, nos. 7 and 8, Oct. 1 and 15, 1925, pp. 136–142 and 152–157. Compares former bureucratic with present economic method and gives details of latter, in which determination of cost of production forms most important part; covers materials, wages, shop costs; factory order system, system of accounts; collection, distribution and booking of costs.

Costs and Output. Shop and Output, J. W. Kennedy. Can. Ry. Club—Official Proc., vol. 24, no. 8, Nov. 1925, pp. 20–34 and (discussion) 34–41, 7 figs. Describes contract wage system employed at Can. Pac. Angus Shops, Montreal, with guaranteed hourly rate; method employed to control and record locomotive repair costs and output.

Toolroom Equipment. Equipment for Railroad Tool-rooms, C. A. Shaffer. Machy. (N. Y.), vol. 32, no. 4, Dec. 1925, pp. 313–314. Selection of equipment; general recommendations for different groups. (Abstract.) Paper presented before Am. Ry. Tool Foremen's Assn.

RAILWAY SIGNALING

Approach Lighting. Track Circuits and Approach Lighting of Signals (Circuiti di binario e illuminazione d'approccio dei segnali), S. Dorati. Rivista Technica delle Ferrovie Italiane, vol. 28, no. 3, Sept. 15, 1925, pp. 88–95, 13 figs. Details of system in which signals are only lighted on approach of train, either by electromechanical devices actuated by train, or by a track circuit, and its application at Sette Bagni Station, where it has been in operation since July 1924.

Track Circuiting. Direct-Current Transient Track-Circuits for Special Locations. Ry. Engr., vol. 46, no. 551, Dec. 1925, p. 431, 1 fig. Instructive particulars of experimental track circuit installed on Lond. & North Eastern Ry.

RAILWAY TRACK

Welding. Report of Committee on Way Matters. Elec. Traction, vol. 21, no. 10, Oct. 1925, pp. 529–533, 4 figs. Standardization of frogs, tongue switches and hard center for special track work; welded rail joints; surface hardening of rails at mill and on street; "Bary" process; arc-welding processes for repairs to rails and manganese steel; rail-joint welding; welding cupped rail ends; welding manganese steel; recommendations; design of substitute ties; reduction of noise in car operation. Committee report to Am. Elec. Ry. Assn.

REDUCTION GEARS

Involute Teeth and. Reduction Gearing and Involute Teeth, M. Delaporte. Shipbldg. & Shipg. Rec., vol. 26, no. 23, Dec. 3, 1925, pp. 594–595 and 598, 8 figs. Remarks based on earlier paper by author in which conclusions was reached that conservation in service of teeth profile demands that they should be devoid of flexibility and compressibility as far as possible. Translated from paper read before Assn. Technique Maritime & Aeronautique.

REFRIGERANTS

Critical Constants. Problem of the Intermediate Fluid in Refrigerating Machines (Il problema del fluido intermediario nelle macchine frigorifere), E. Foà. Industria, vol. 39, no. 20, Oct. 31, 1925, pp. 532–537, 3 figs. Discusses method of studying influence of choice of intermediary liquid on work, and volume of liquid; application to sulphur anhydride, carbon anhydride, and ammonia.

Properties. Small Refrigerating Plants and the Thermodynamical Properties of Refrigerating Liquids, E. Griffiths and J. H. Awbery. British Cold Storage & Ice Assn.—Proc., vol. 21, no. 2, 1924–1925, pp. 63–104 and (discussion) 105–107. Survey of properties of refrigerating fluids, including carbon dioxide, ammonia, sulphur dioxide, ethyl chloride, butane and isobutane; machines of turbo-compressor type; construction of temperature-entropy diagrams for various fluids; general considerations regarding small machines; sketch of novel mechanical features found in small machines; classified list of small plants and list of plants of less than one horsepower; use of entropy-temperature diagram; etc. Bibliography.

REFRIGERATING MACHINES

Absorption. Absorption Refrigerator. Elec. World, vol. 86, no. 23, Dec. 5, 1925, p. 1161, 2 figs. Domestic electric refrigerator operates on continuous-absorption principle; no moving parts required; total pressure in system always same.

Compressors. High Revolution Compressors for Marine Refrigeration, E. Markham. Refrig. Eng., vol. 12, no. 4, Oct. 1925, pp. 111–116. Essentials of good refrigeration compressor; reasons for making machine vertical in preference to horizontal; reliability, efficiency, safety in operation and low initial cost; silence in operation and easy overhaul.

REFRIGERATING PLANTS

Corrosion in. Corrosion in the Refrigerating Industry, W. G. Whitman, E. L. Chappell and J. K. Roberts. Refrig. Eng., vol. 12, no. 5, Nov. 1925, pp. 158–165, 11 figs. Survey of previous work; laboratory study of important factors and of various methods for corrosion prevention. Condensation of report submitted to Committee on Corrosion of Am. Soc. Refrig. Engrs.

REFRIGERATION

Brines, Properties of. Properties of Salt Brine, C. H. Herter. Ice & Refrigeration, vol. 69, nos. 2, 3 and 6, Aug., Sept. and Dec. 1925, pp. 109–111, 162–163 and 383–386, 3 figs. Aug.: Discusses new chart facilitating all usual calculations with chloride of sodium brine, NaCl, based on latest researches available; influence of temperature; example of use of chart; curve of freezing points; specific heat. Sept.: New direct reading graphical chart giving results of latest researches on the various properties of calcium chloride brine; heat content at all temperatures; freezing points at various strengths; concentration, volume and weight of solutions. Dec.: Curves indicating strength, freezing point, and specific heat of pure magnesium brine; deviation of commercial mixed chloride brines from pure magnesium and straight 75 per cent calcium chloride brines; properties of commercial calcium-magnesium chloride.

Cooling Apparatus. The Production of Low Temperatures, B. von Platen and C. G. Munters. Refrig. Eng., vol. 12, no. 5, Nov. 1925, pp. 142–148, 9 figs. Describes principles for two kinds of refrigerating apparatus, one being especially suitable as to efficiency for relatively greater difference in temperature of condenser and cooler and other for relatively smaller difference. Translated from Teknisk Tidskrift, Mar. 21, 1925, pp. 89–95, 11 figs.

RIVETS

High Temperatures, Effects of. High Temperatures Hurt Rivets, A. L. Spencer, Jr. Iron Age, vol. 116, no. 23, Dec. 3, 1925, pp. 1521–1522, 1 fig. Tests show that heating above 1950 deg. fahr. produces structure which will not withstand rapid alternate compression and tension. (Abstract.) Paper read before Am. Inst. Steel Constr. See also Iron Trade Rev., vol. 77, no. 22, Nov. 26, 1925, pp. 1341–1344, 2 figs.

ROLLING MILLS

Bar. Rolls First Steel Bars on New 14-Inch Mill. Iron Trade Rev., vol. 77, no. 24, Dec. 10, 1925, pp. 1460–1461 and 1470, 2 figs. New continuous mill of Ford Motor Co.'s River Rouge plant, built by Morgan Constr. Co., Worcester, Mass, is electrically operated and consists of 6 stands of 18-in. rolls and 4 stands of 14-in. rolls.

ROLLS

Cast-Iron. Cast-Iron Rolls for Rolling Mills (Fabrication des cylindres de laminoirs en fonte), Fondérie Moderne, vol. 19, Oct. 1925, pp. 213–214. Describes a method of production which does away with cupola-melted metal for pouring and increases hardness of rolls, resulting in reduced cost of repairs of wear.

S

SAND, MOLDING

Selection and Use of. Bad Castings Caused by Improper Use of Sand, Rob. Gregg. West. Machy. World, vol. 16, no. 12, Dec. 1925, pp. 509–510. Molding and casting conditions that need careful study in selection of proper sand for various jobs; important characteristics of sand which should be considered for various kinds of jobs; chemical analysis of sand.

Steel Castings. Steel Moulding Sands and Their Behaviour under High Temperatures, A. L. Curtis. Iron & Steel Inst.—Carnegie Scholarship Memoirs, 1925, 89 pp., 67 figs. partly on supp. plates and folders. Deals with natural argillaceous sands, and artificial "steel facing sands" or proprietary mixtures; method adopted and apparatus used for testing steel molding sands under high temperatures; permeabilities of steel molding sands; photomicrographs. See also (abstract) in Foundry Trade Jl., vol. 32, nos. 473, 475, 482, 483, and 484, Sept. 10, 24, Nov. 12, and 26, 1925, pp. 213–214, 263–269, 409–412, 423–426, and 443–447, 26 figs.

SAWS

Safety in Use and Care. Safety in the Use and Care of Saws, S. H. Disston. Safety, vol. 4, no. 4, Sept.-Oct. 1925, pp. 101–105, 8 figs. Notes on development of saws; what manufacturer is doing to promote cause of safety with saws.

SCALES

Railway-Track. The Weighing Scale—An Instrument of Precision, E. Sheldon. Am. Mach., vol. 63, no. 24, Dec. 10, 1925, pp. 933–936, 7 figs. Building large railroad-track scale; ponderous in weight but simple in construction; parts must be delicately balanced; operation of sealing.

SCREW THREADS

Cutting. Can Screw-Cutting Results be Predetermined by a Shadow Inspection of the Chases? A. F. Breitenstein. Am. Mach., vol. 63, no. 25, Dec. 17, 1925, p. 974. From data given it is obvious that cutting accuracy of thread chasers can be best determined by inspecting the elements of screws cut with chasers.

Standardization. Thread Standardization as Related to Cost and Delivery, C. W. Bettcher. Am. Mach., vol. 63, no. 24, Dec. 10, 1925, pp. 929–930. Two primary classifications; review of work already accomplished; unnecessary expense resulting from special threads; gradual disappearance of V-threads.

SEAPLANES

Blackburn Torpedo. A New Blackburn Torpedo Seaplane. Flight, vol. 17, no. 45, Nov. 5, 1925, pp. 716–717, 6 figs. Particulars of the "Velos," having a span of 48 ft., overall length 36 ft., and height 12 ft. 6 in.; carried a Mark VIII torpedo; Napier "Lion" engine.

SEPARATORS

Ash and Fuel. Recovering Fuel from Ash and Clinker, C. H. S. Tupholme. Elec. Rev., vol. 97, no. 2504, Nov. 20, 1925, pp. 804–806, 4 figs. Modern methods of separation and types of washers and separators.

SHAFTS

Torsional-Stress Concentrations. Torsional Stress Concentrations in Shafts of Circular Cross-Section and Variable Diameter, L. S. Jacobsen. Am. Soc. Mech. Engrs.—advance paper, for mtg. Nov. 30–Dec. 4, 1925, 22 pp., 13 figs. Points out electrical, experimental method for finding torsional-stress distribution in cylindrical shafts of circular cross-section and of any axial outline; method has been applied to problem considered by F. A. Willers, and paper includes series of curves that will enable designer to find, at glance, maximum torsional stress in shaft of 2 diameters for various diameter and fillet proportions.

Vibrations. Torsional Vibrations in Reciprocating Shafts, G. R. Goldsbrough. Roy. Soc.—Proc., vol. 109, no. A749, Sept. 1, 1925, pp. 99–119. Analytical investigation of vibrations about steady motion of elastic shaft having engine at one end and mass operating against resistance at other end; results are applicable only to relatively low-speed engines.

Vibration Phenomena of a Loaded Unbalanced Shaft while Passing through Its Critical Speed, A. L. Kimball, Jr., and E. H. Hull. Am. Soc. Mech. Engrs.—advance paper, for mtg. Nov. 30–Dec. 4, 1925, 18 pp., 13 figs. Presents in clear manner, with experimental demonstration, discussion of peculiar vibration phenomena to which unbalanced loaded shaft is subject while passing through its critical speed; basic theory is given from somewhat new viewpoint, after which experimental demonstration, which gives quantitative check on theory, is described.

SILICON STEEL

Properties and Types. Silicon Steel, W. E. Ruder. Am. Iron & Steel Inst.—advance paper, for mtg. Oct. 23, 1925, 8 pp.; also (abstract) in Iron Age, vol. 116, no. 18, Oct. 29, 1925, pp. 1170–1171. Constitution, mechanical properties, magnetic uses and magnetic properties; thickness of sheets; effect of punching strains; mechanical condition of sheets; testing.

SLIDE RULES

A. E. G. Special Slide Rules (Sonder-Rechenschieber), F. Bahlecke. Werkstattstechnik, vol. 19, no. 20, Oct. 15, pp. 726–730, 11 figs. Details of design and application for approximate calculation of loads and velocities of belting, weight of sheet iron of a given thickness and surface, and other problems connected with machine-tool work; numerical examples.

SPARK PLUGS

Automobile. Automobile Spark Plugs (La bougie d'automobile), Nature (Paris), no. 2686, Sept. 26, 1925, pp. 193–196, 5 figs. Parts and their functions; development of various types of plugs; Champion, Sol, Morel, and Colin plugs.

SPRINGS

Automobile. Making Springs for Motor Vehicles, A. Murphy. Can. Foundryman, vol. 16, no. 11, Nov. 1925, pp. 21–23, 5 figs. Practice and equipment of Dowsley Spring & Axle Co., Chatham, Ont.

Corrosion-Resisting Coating. Recent Progress in Coating Steel Springs to Resist Corrosion, Jos. K. Wood. Am. Mach., vol. 63 no. 25, Dec. 17, 1925, pp. 981–984. Application of non-corrosive metallic coatings to steel spring surfaces; effect of processes on spring characteristics; Madsen process and its promise for successful solution of problem.

Elastic and Fatigue Properties. An Outline for the Application of Fatigue and Elastic Results to Metal Spring Design, T. M. Jasper. Am. Soc. Mech. Engrs.—advance paper, for mtg. Nov. 30–Dec. 4, 1925, 11 pp., 9 figs. Deals particularly with steel springs used for shock-absorbing purposes and for recuperating machinery; problem of design of springs may be divided into parts: first, question of static elastic and fatigue properties of material to be used in their construction, and second, shape of springs desired, together with distribution of stresses developed in their use for given deformation; results of investigation of static properties of steel carried out Eng. Experiment Station of Univ. of Ill.

Helical. Formulas for the Design of Helical Springs of Square or Rectangular Steel, C. T. Edgerton. Am. Soc. Mech. Engrs.—advance paper, for mtg. Nov. 30–Dec. 4, 1925, 15 pp. Author points out lack of formulas for calculating any except springs of square-bar steel, and then develops formulas for rectangular-bar steel based on work of St. Venant; for solution of these formulas he gives tabulated values for two variables which depend on ratio of bar's cross-sectional dimensions; appendix contains 4 examples in which application of formula is illustrated.

Phosphor-Bronze Helical Springs from the Standpoint of Precision Instruments, W. G. Brombacher. Am. Soc. Mech. Engrs.—advance paper, for mtg.

Nov. 30–Dec. 4, 1925, 16 pp., 8 figs. Results of tests made on springs investigated at Bur. of Standards to obtain knowledge useful in design of springs for precision instruments; characteristics of spring material, method of construction of springs, apparatus in which springs were tested, and procedure followed are set forth; results relate to stiffness, maximum fiber stress, hysteresis, after-effect, drift, and buckling.

STANDARDIZATION

National, Need for. Why Standardization—, C. E. Skinner. Factory, vol. 35, no. 5, Nov. 1925, pp. 723–724, 748, 750, and 752. Author shows clearly need for national standards movement, and makes plain the difference between standardization and simplification. On p. 722 are given statements by G. Swope, J. W. Lieb, L. F. Loree, G. B. Cortelyou and J. A. Farrell, on why they believe in standardization.

STANDARDS

Austrian ONIG Reports. Report of the Austrian Industrial Standards Committee (Österr. Normenausschuss für Industrie und Gewerbe), Sparwirtschaft, no. 9, Sept. 1925, pp. 83–88 (OeNIG), 2 figs. Proposed standards for radial bricks, paving bricks, slug bricks, loam, and clay for building material.

German N. D. I. Reports. Report of the German Industrial Standards Committee (Normenausschuss der deutschen Industrie). Maschinenbau, vol. 4, no. 19, Sept. 17, 1925, pp. 963–965, 1 fig. Details of proposed standards for open-face envelopes, milling cutters, limit gages, standard gages, plug and ring gages, and die stocks.

Report of the German Industrial Standards Committee (Normenausschuss der deutschen Industrie). Maschinenbau, vol. 4, no. 21, Oct. 15, 1925, pp. 1063–1066, 2 figs. Proposed standards for spur and bevel gear teeth, and riveted steel tubes.

Report of the German Industrial Standards Committee (Neue Dinormblätter). Werkstattstechnik, vol. 19, no. 18, Sept. 15, 1925, pp. 681–683, 1 fig. Details of proposed standards for threaded square units for spindles, cam wheels, and shafts; also gages.

Report of the German Industrial Standards Committee (Neue DINormblätter). Werkstattstechnik, vol. 19, Oct. 1, 1925, pp. 715–717, 2 figs. Proposed standards for round nuts with four grooves, and round nuts with cross holes.

Report of the German Industrial Standards Committee (Neue DINormblätter). Werkstattstechnik, vol. 19, no. 20, Oct. 15, 1925, pp. 747–749, 2 figs. Proposed standards for plates for welding of quadrilateral and trilateral profiles.

Report of the German Industrial Standards Committee (Normenausschuss der deutschen Industrie). Gas- u. Wasserfach, vol. 68, no. 39, Sept. 26, 1925, pp. 615–617. Proposed standards for a nomenclature of technical gases, covering gases from liquid and solid fuels.

STEAM

High-Pressure. The Production of High-Pressure Steam. Eng. Progress, vol. 6, no. 10, Oct. 1925, pp. 313–314, 1 fig. High-pressure steam plant of 100-atmos. pressure erected at Wiener Lokomotivfabrik, at Vienna, Austria, according to designs of Prof. Löffler, for purpose of testing his new method of generating high-pressure steam for permanent service.

Recent Steam Economies under the Influence of High-Pressure Steam, (Neuzeitliche Dampfwirtschaft unter dem Einfluss des Hochdruckdampfes), F. Wintermeyer. Brennstoff- u. Wärmewirtschaft, vol. 7, no. 16, Aug. (2d no.) 1925, pp. 313–316. Discusses work of Schmidt, Benson and Loeffler; choice of feedwater, preheating, pulverized-coal firing, high-pressure steam in turbines, back pressure and piston engines.

The Value of Higher Steam Pressures in the Industrial Plant, Wm. F. Ryan. Am. Soc. Mech. Engrs.—advance paper, for mtg. Nov. 30–Dec. 4, 1925, 21 pp., 9 figs. Points out value of higher steam pressures; shows that gains from high pressure are greater than in central station, and except for question of suitable feedwater for high-pressure boilers, problems involved are less difficult; relative cost of power for varying initial pressures is estimated; relative efficiency of turbine and engine prime movers, and application of higher pressures to manufacturing equipment, are discussed; it is indicated that pressures up to present commercial limit, about 1200 lb. per sq. in. may be used advantageously, under given conditions.

Refuse Incinerator. Atlanta Now Sells Excess Steam from Refuse Incinerator, H. J. Cates. Eng. News-Rec., vol. 95, no. 23, Dec. 3, 1925, pp. 922–923, 2 figs. Of nearly a pound of steam per pound of refuse, 36 per cent is used for works purposes and 64 per cent sold for use in making gas.

Reheating. Steam Economy, W. D. Wylde. Indus. Mgmt. (Lond.), vol. 12, no. 11, Nov. 1925, pp. 528 and 530. Discusses steam reheating, including method and economy of reheating, lowering of fuel consumption, and saving of steam.

Research. Present State of Research on Physical Properties of Steam (L'état actuel des recherches relatives à l'étude des propriétés physiques de la vapeur d'eau), C. Roszak. Société des Ingénieurs Civils de France—Mémoires et Compte Rendu des Travaux, vol. 78, no. 7–8, July-Aug. 1925, pp. 570–583. Results of recent German, Swiss, and American research work; discusses saturated steam, including total heat, latent heat of vaporization, conductivity; superheated steam, including definition, specific heat, total heat, specific volume; concludes that up to 60 atmos. German results may safely be used.

STEAM ACCUMULATORS

High-Pressure Steam Storage. High-Pressure Steam Storage (Wärmespeicher-Dampfleistungsausgleich), H. F. Lichte. Wärme, vol. 48, no. 40, Oct. 2, 1925, pp. 505–507, 6 figs. Describes Müller type of storage which uses surplus steam from boilers to heat feedwater to boiler temperature; cold feed, or feed preheated by economizer, flows steadily into storage vessel as long as boiler pressure is within plus or minus $1^1/_2$ lb. of its normal value; if pressure falls lower than $1^1/_2$ lb. per sq. in. below normal, supply of water to storage is checked and it is interrupted completely when boiler pressure reaches 3 lb. per sq. in. below normal; when pressure exceeds $1^1/_2$ lb. above normal, supply of feed to storage is increased; advantages of system.

STEAM ENGINES

Isolated Plants. The Steam Engine Still in Favor in the Isolated Plant. Power, vol. 62, no. 22, Dec. 1, 1925, pp. 834–835, 4 figs. Kinds of service to which steam engine is especially adapted and factors that are reacting in its favor.

Lubrication of Cylinders. Practical Instructions on Lubrication of Steam-Engine Cylinders, P. B. Jensen. Nat. Engr., vol. 29, no. 12, Dec. 1925, pp. 595–597. Cylinder should be examined after engine stops; point of introduction of oil; amount of compounding necessary; effect of load and type of engine on lubrication; classification of steam-cylinder oils.

Uniflow. Unaflow Engines Drive High-Pressure Compressors, J. Stumpf. Power, vol. 62, no. 24, Dec. 15, 1925, pp. 940–941, 3 figs. Single-beat valves and special valve gear used on German engines; clearance volume very small; compressors use six stages, compressing to 3300 lb. per sq. in.

STEAM GENERATORS

Pulverized-Coal-Burning. New Steam Generator. Iron Age, vol. 116, no. 25, Dec. 17, 1925, p. 1707. Evaporates 35 lb. of water to 1 sq. ft. of heating surface per hr.; installation in plant of Taylor Bros. in England, developed by Combustion Eng. Corp, New York.

STEAM METERS

Construction. Industrial Measuring of Steam (La mésure industrielle de la vapeur), J. Welter. Chaleur et Industrie, vol. 6, no. 66, Oct. 1925, pp. 451–458, 9 figs. Discusses placing of steam meters at various points of a plant, defects of steam meters generally; calculates diaphragms, orifices and other parts of steam meters, enumerates conditions that an efficient steam meter must fill.

STEAM PIPES

Heat-Loss Measurement. Heat-Flow Meter and its Use in Determining Heat Losses in Steam Piping (Der Wärmeflussmesser und seine Verwendung zur Feststellung von Wärmeverlusten an Dampfleitungen) Arnold Körting. Gas- und Wasserfach, vol. 68, no. 46, Nov. 14, 1925, pp. 715–719. Details of E. Schmidt's method and apparatus consisting of rubber strip containing number of thermocouples placed round surface giving off heat, and measuring difference in temperature at its interior and exterior surfaces by means of a milli-voltmeter; may be used also for testing insulating material accurately and rapidly.

Power-Plant. Steam Piping System in Modern Power Plants, W. Tallmadge. Universal Engr., vol. 42, no. 4, Oct. 1925, pp. 22–24. Discusses strength of pipe, supports, flexibility, joints, valves, etc. Paper read before Progressive Council No. 12, Universal Craftsmen's Council of Engrs.

STEAM POWER PLANTS

Combined Heating and Power. Surplus Energy (Ueberschussenergie), F. Niethammer. Wärme, vol. 61, nos. 35 and 36, Aug. 28 and Sept. 4, 1925, pp. 446–449 and 460–463, 2 figs. Gives leading particulars concerning equipment and operating conditions in large number of installations where power and heating loads are operated conjointly; examples are cited from following industries: sugar refineries, textile works, chemical, paper and leather plants, briquette factories, and electricity works operating in conjunction with district heating schemes; reviews use of mixed-pressure turbines, steam storages, back-pressure regulators, waste-heat boilers and other equipment; outlines difficulties in dispensing of surplus energy from and in industrial concerns.

Costs. Cost of Energy of Power Plants with Heat Engines (Energikostnad vid kraftanläggningar med värmemotorer), M. T. Lindhagen. Teknisk Tidskrift, vol. 55, no. 31, Aug. 1, 1925, pp. 129–133 (Elektroteknik), 7 figs. Discusses installation and running cost of large steam power plant, also smaller plant run with gas engines, Diesel engines, steam engines, and turbines; cost of power alone and combined with heating.

Economy. Some Examples of Possible Savings in Industrial Power Plants, A. F. Sheehan. Nat. Engr., vol. 29, no. 12, Dec. 1925, pp. 563–565. A number of specific cases cited in which considerable savings could be accomplished.

Efficiency. Maintaining Power Plant Efficiency, C. C. Hermann. Power House, vol. 18, no. 22, Nov. 20, 1925, p. 19. Points out that engineer must understand equipment, guard against leaks and know how to obtain coöperation.

STEAM POWER PLANTS

500-Hp., Design of. Designing a 500-Horsepower Steam Power Plant, C. L. Hubbard. South. Engr., vol. 42, no. 6, and vol. 43, nos. 1, 2, 3, 4, 5, 6, 8, 9 and 10, Feb., Mar., Apr., May, June, July, Aug., Oct., Nov. and Dec. 1925, pp. 48–51, 48–53, 56–51, 52–58, 53–58, 44–49, 44–49, 40–45, 37–44 and 57–64, 55 figs. Feb.: Methods of computing boiler capacity. Mar.: Fire-tube and water-tube boilers and their use in present problem; superheaters and economizers. Apr.: Boiler furnaces, stokers, forced and induced draft, size of fans and air volume and pressure. May: Pulverized fuel, oil-burning equipment, arrangement of burners and storage tanks. June: Chimneys and smoke connections, chimney design, chimney construction and breeching. July: Boiler feedwater, methods of treatment, water purifying equipment. Aug.: Feedwater heating, design of heaters, most efficient arrangement of heaters. Oct.: Boiler-feed pumps, their selection, speed regulation, pumps for heating systems and general layout of feed equipment. Nov.: Determining best arrangement, layout and size of power house, together with coal-handling equipment. Dec.: Piping material and fittings, pipe supports, pipe vibration and laying out pipe system.

Fuel Economy. Why Management Is Responsible for Excessive Coal Bills, Thos. A. Marsh. Factory, vol. 35, no. 6, Dec. 1925, pp. 891–893 and 988. Author claims that many plants could reduce their fuel bills 10 per cent with practically no expenditure for equipment, simply by improved operating methods; discusses steps toward coal-bill reduction.

Hotels. Economics of Heat and Power Production in Modern Hotels, E. Douglas. Nat. Engr., vol. 29, no. 12, Dec. 1925, pp. 591–594. Data on hotel power-plant service requirements and how they can be most economically provided.

Office Buildings. Office-Building Plant Saves by Studying Costs, Wm. R. Goodwin. Power, vol. 62, no. 25, Dec. 22, 1925, pp. 962–966, 7 figs. As result of study, motor-generator sets were installed for purchase of power in excess of that capable of being generated from heating steam, in home office building of Conn. Mutual Life Insurance Co., Hartford.

Rating System for Small. Getting Best Results from the Small Power Plant, R. S. Twogood. Indus. Mgmt. (N. Y.), vol. 70, no. 6, Dec. 1925, pp. 323–330, 5 figs. Practical rating system and how it helps efficiency.

Records. An Unfailing Way to Reduce the Costs of Steam, H. E. Collins. Mgmt. & Admin., vol. 10, no. 6, Dec. 1925, pp. 333–337, 2 figs. Points out that all factors entering into power-plant operation can be measured; instruments are available to produce records, from which accurate costs can be determined and deficiencies in operation corrected before they amount to serious losses.

STEAM TURBINES

Bleeder. Bleeder Turbines for Industrial Heating (Les turbines à soutirage de vapeur pour les chauffages industrials). Génie Civil, vol. 87, no. 20, Nov. 14, 1925, pp. 413–416, 5 figs. Details of design and operation of bleeder or back-pressure turbines; power available and cost per kw-hr.; with examples of installation.

Steam Bleeding and Turbine Performance, C. D. Zimmerman. Mech. Eng., vol. 47, no. 12, Dec. 1925, pp. 1144–1148, 20 figs. Results of tests showing effect of steam bleeding on total power-plant efficiency, also effect of changes in vacuum and superheat on turbine and condenser performance.

Bucket Vibration. Tangential Vibration of Steam-Turbine Buckets, W. Campbell and W. C. Heckman. Am. Soc. Mech. Engrs.—advance paper, for mtg. Nov. 30–Dec. 4, 1925, 25 pp., 15 figs. Describes how research dealt with in paper before Society in 1924 was extended to include tangential vibration; substantially same testing apparatus was used and same methods of protection adopted; in unsymmetrical reaction buckets compound vibration lying most nearly in plane of wheel is, by definition, treated as tangential vibration; methods described suffice for protection against any combined or intermediate type.

Combined Power and Heating Processes. High Efficiency in the Use of Steam. Power, vol. 62, no. 22, Dec. 1, 1925, pp. 846–847, 2 figs. Discusses combined power and heating process and cites examples of practical applications that are earning dividends for their owners.

Intermediate Superheating. Intermediate Superheating, K. Thielsch. Elecn., vol. 95, no. 2477, Nov. 6, 1925, pp. 524–526 and 533, 6 figs. Its employment in power stations with condensing turbines; general principles; temperature and pressure limits; possible methods. Abstract, trans. from AEG Mitteilungen.

STEEL

Alloy. See ALLOY STEELS.

Silicon. See SILICON STEEL.

Pearlitic. The Retarded Solution of Granular Pearlite at Point of Transformation (Die verzögerte Auflösung körnigen Perlits beim umwandlungspunkt), H. Jungbluth. Stahl u. Eisen, vol. 45, no. 47, Nov. 19, 1925, pp. 1918–1919, 1 fig. It is shown that retarded solution of granular pearlite can be indicated on differential curve and, under favorable conditions, formation of granular pearlite with annealing of steel can also be observed.

Stainless. Recent Developments in Stainless Steel, D. G. Clark. Am. Iron & Steel Inst.—advance paper, for mtg. Oct. 23, 1925, 28 pp., 7 figs.; also (abstract) in Iron Age, vol. 116, no. 18, Oct. 29, 1925, pp. 1172–1173. Deals with steels wherein chromium is predominant alloy; history and patents; processes; types of stainless steel; standard cutlery type; physical properties; resistance to heat; heat treatment; hard cutlery type; high-carbon, soft-steel and stainless iron types; physical properties of stainless iron for turbine blades; valve-steel and nickel types; effect of various corrosive reagents.

Tool. See TOOL STEEL.

Vanadium. See VANADIUM STEEL.

STEEL CASTINGS

Cleaning. Clean Steel Castings Economically, F. B. Jacobs. Foundry, vol. 53, no. 22, Nov. 15, 1925, p. 922, 1 fig. Methods employed at West Steel Castings Co., Cleveland.

Heat Treatment. Heat-Treatment Data on Quality Steel Castings, A. E. White. Am. Soc. Mech. Engrs.—advance paper, for mtg. Nov. 30–Dec. 4, 1925, 15 pp., 7 figs. Summarizes study which has been made on heat-treatment practice for quality steel cast-

ings; gives results of laboratory tests on dendritic and dentrite-free steels after annealing, normalizing, drawing, and spheroidizing treatment; records large number of plant tests; results show that normalizing and drawing treatment gives superior results to those obtainable by annealing or spheriodizing.

Obstructed Contraction, Effect of. Effects of Obstructed Contraction on Steel Castings (Folgeerscheinungen der gehinderten Schwindung an Stahlformgussstücken), H. Malzacher. Giesserei-Zeitung, vol. 22, no. 21, Nov. 1, 1925, pp. 653–657, 13 figs. Notes on contraction and forces resisting it; hot cracks; stresses; practical examples.

Purchase of. Salient Facts Which Should Govern the Purchase of Steel Castings, C. B. Tibbetts. West. Machy. World, vol. 16, no. 11, Nov. 1925, pp. 466–467 and 474, 2 figs. Outline of what may be expected from steel castings of any one of several analyses; purchaser should first of all analyze conditions under which casting is to be used; before any definite design is settled upon foundry should be consulted and physical requirements checked over again with foundry.

STEEL, HEAT TREATMENT OF

Critical Temperatures. Steel and Its Heat Treatment, H. M. Boylston. West. Machy. World, vol. 16, no. 11, Nov. 1925, pp. 494–496, 2 figs. Critical points in iron and steel; explains reasons why and how physical properties of steel can be controlled almost at will by commercial heat treatments of various kinds.

Hardening and Tempering. Heat Treatment and Metallography of Steel, H. C. Kneer. Forging—Stamping—Heat Treating, vol. 11, no. 11, Nov. 1925, pp. 386–390, 11 figs. Hardening and tempering.

STEEL MANUFACTURE

Open-Hearth Boils. Differences in Open-Hearth Boils, H. D. Hibbard. Iron Age, vol. 116, nos. 23, 24, and 25, Dec. 3, 10 and 17, 1925, pp. 1511–1513, 1605–1606, and 1671–1672. Classification according to degree and violence; consideration of uses and characters of 10 recognized types; causes and effects of boils. Dec. 10: Dead bath and almost dead bath; incipient, gentle and moderate boil. Dec. 17: Decarbonizing effects and Talbot reaction; effervescing steels; Martin and Siemens process.

STOKERS

Fuel Preparation for. Fuel Preparation for Chain-Grate Stokers, F. C. Duennes. Power, vol. 62, no. 21, Nov. 24, 1925, pp. 798–799, 2 figs. Discusses two distinct operations involved in fuel preparation, namely, sizing, and wetting.

Selection. Mechanical Stokers Offer Savings to Many Hand-Fired Plants. Power, vol. 62, no. 22, Dec. 1, 1925, pp. 844–845, 5 figs. Proper selection of stoker necessary; size of plant an influencing factor.

STREET RAILWAYS

Locomotives. Hanomag Street Railway Locomotives (Hanomag-Strassenbahn-Lokomotiven). Hanomag Nachrichten, vol. 17, no. 142, Aug. 1925, pp. 129–130, 1 fig. Advantages of steam locomotives and their field of application; design and specifications of various types used in Holland, Germany, and Colombia, with and without housing.

T

TEMPERATURE CONTROL

Industrial Buildings. Modern Methods for Temperature Control of Industrial Buildings, C. L. Hubbard. Nat. Engr., vol. 29, no. 12, Dec. 1925, pp. 559–562, 5 figs. General considerations in design of heating systems and outline of control methods.

TEMPERATURE MEASUREMENT

High Temperatures. The Measurement of High Temperatures (Merkblatt zur Messung hoher Temperaturen). Stahl u. Eisen, vol. 45, Nov. 5, 1925, pp. 1850–1854. Deals with measurement by means of thermocouples and radiation pyrometers. Notes and suggestions presented by Steel-Works Committee, Materials Committee, and Heat Bureau of German Iron & Steel Inst.

Instruments. Test Code on Instruments and Apparatus. Mech. Eng., vol. 47, no. 12, Dec. 1925, pp. 1161–1164, 4 figs. Preliminary draft of Chapter 3, Temperature Measurement, Section 1. Deals with instruments and apparatus available for measuring temperature and their installation.

TERMINALS, LOCOMOTIVE

Drop Pits for Wheel Removal. Drop Pits for Removing Wheels at Engine Terminals, J. D. Rogers. Baldwin Locomotives, vol. 4, no. 2, Oct. 1925, pp. 54–57, 8 figs. Describes drop pit for removing wheels and how they are used.

TEXTILE MILLS

Water Supply. Water Supply for Textile Mills, C. L. Hubbard. Textile Wld., vol. 68, no. 19, Nov. 7, 1925, pp. 71 and 73–74, 5 figs. General survey of methods employed to purify water for boiler feeding and process work; impurities commonly found; removal by means of filters, settling tanks, heat, lime, soda, combined lime and soda, and zeolite; boiler compounds; water-softening apparatus.

THERMIT WELDING

Developments. Thermit Welding Development, J. H. Deppeler. Am. Welding Soc.—Jl., vol. 4, no. 10, Oct. 1925, pp. 58–64. Description of process; developments; work which has been done in improvement of physical qualities of thermit steel.

THERMODYNAMICS

Third Law. New Edition of Nernst's Monograph on Third Heat Law (Zur Neuauflage der von W. Nernst veröffentlichten Monographie über den 3. Wärmesatz), Schmolke. Dinglers polytechnisches Journal, vol. 340, no. 16, Aug. 1925, pp. 181–186, 2 figs. Develops scientific and mathematical bases of Nernst theorem and gives examples of its application.

TIRES, RUBBER

Wear. Wear of Automobile Tires on Standard Road Surfaces, M. C. McNown. Automotive Mfr., vol. 67, no. 7, Oct. 1925, pp. 22–24. Exact data from a thorough investigation, not yet finished, into the various tire and highway surface factors which influence wear.

TOOL STEEL

Circular Forming Tools. Steels for Circular Forming Tools (Formscheibenstähle), F. Karpinski. Werkstattstechnik, vol. 19, no. 19, Oct. 1, 1925, pp. 689–695, 23 figs. Discusses bases for calculation of steels and shows new methods by means of special calculating device; also graphic methods for determining forms.

TRACTORS

Three-Wheeled. German Three-Wheeled Tractor is Fitted with Diesel Powerplant. Automotive Industries, vol. 53, no. 23, Dec. 3, 1925, pp. 944–945, 4 figs. Single driving wheel has one set of stationary and one of adjustable lugs; auxiliary wheels for use in emergencies; manufactured by Benz Works of Mannheim, and known as Benz-Sending tractor.

V

VANADIUM STEEL

Hardness. Vanadium Steels (Zur Kenntnis der Vanadinstähle), E. Maurer. Kruppsche Monatshefte, vol. 6, Sept. 1925, pp. 165–169, 2 figs. Shows that vanadium hardenite does not exist, nor a point similar to pearlite; carbide dissolves gradually with increasing temperature like secondary cementite; on basis of mainly physical tests formula of carbide is V_4C_3.

VAPORS

Pressures. Pressure-Temperature Charts—Extended Ranges, Geo. Galingaert and D. S. Davis. Indus. & Eng. Chem., vol. 17, no. 12, Dec. 1925, pp. 1287–1289, 6 figs. It has been shown that empirical method of Cox of plotting vapor-pressure data was suitable for range of 0 to 300 deg. cent. in case of several vapors; it is shown in this paper that this method is applicable over very much greater ranges.

VIBROSCOPES

High-Speed Mechanisms, Observation of. Observation of High-speed Mechanisms. Machy. (Lond.), vol. 27, no. 687, Nov. 26, 1925, pp. 270–272, 3 figs. Use of apparatus that causes rapidly moving parts to appear stationary at any point in cycle of movements; arrangement of vibroscope and examples illustrating its use; determining lubrication troubles; locating cause and extent of excessive vibrations.

W

WAGES

Analysis of. The Meaning of Wages, L. Grier. Nature (Lond.), vol. 116, no. 2921, Oct. 24, 1925, pp. 613–617. Discusses certain aspects of wages, and reviews from those aspects certain payments made to or on behalf of employees.

Barth Standard Scale. The Barth Standard Wage Scale, C. G. Barth. Mgmt. & Admin., vol. 10, no. 6, Dec. 1925, p. 357. Method is application of fundamental of Weber's law of discrimination, which declares that for sensations or responses in arithmetical relationship, corresponding stimuli form geometric series.

Payment Plan. Our Wage Payment Recognizes Cost of Living, Length of Service, Efficiency. Factory, vol. 35, no. 6, Dec. 1925, pp. 917–918 and 980. Plan adopted by Palmolive Co., Chicago, is based on idea that company has no desire to purchase labor on market as cheaply as possible, but rather that it should be procured at price commensurate with value of particular job; prospective employee compensation that will, in measure, offset fluctuations in cost of living, and provide method for recognizing and remunerating increased efficiency and loyalty.

Piece-Work Plan for Office Workers. This Wage-Making Plan Has Cut Our Office Costs for Three Years, P. T. Tobey. System, vol. 48, no. 4, Oct. 1925, pp. 405–408, 7 figs. Particulars of plan devised by Holeproof Hosiery Co. for paying certain office workers according to amount of satisfactory work they produced.

WATER POWER

Ontario, Canada. Developing Ontario's Water Power. Power House, vol. 18, no. 20, Oct. 20, 1925, pp. 89–90. With water-power resources of Ontario, including potential power of Niagara River, permitting of an installation of 9,000,000 hp., resources of province are but from 18 to 25 per cent developed.

Small, Development by Factory Owners. The Development of Small Water-powers by the Factory Owner, F. Johnstone Taylor. Mech. World, vol. 78, no. 2030, Nov. 27, 1925, p. 425. Points out that if factory is located near any appreciable volume of running water it behooves owner in his own interest to have its potential value investigated; machinery for medium and for low falls; waste water, storage, selling power.

Steam Power in Its Relation to. Steam-Power in Its Relation to the Development of Water-Power, R. C. Powell. Am. Inst. Elec. Engrs.—Jl., vol. 44, no. 12, Dec. 1925, pp. 1291–1295, 8 figs. Draws attention to desirability of development of water-power resources of country on comprehensive economic basis and discusses some of features of steam power in connection with economic development of water power; points out limitations of cost curves frequently used in comparing costs of water and steam power, and gives simple method whereby minimum cost of power may be found for assumed water-power development with auxiliary steam power.

WATER TREATMENT

Lime-Soda Process. Lime and Soda Ash Method, O. T. Rees. Pac. Ry. Club—Jl., vol. 9, no. 5, Aug. 1925, pp. 5, 7, 9, 11, 13, 15, 17, and 19. Discusses types of equipment for lime-and-soda method of treating water and systems employed by Santa Fe Railway.

WELDING

Electric. See ELECTRIC WELDING, ARC; ELECTRIC WELDING, RESISTANCE.

Heat Effect on Steel. The Effect of Heat on Steel, Especially During Fusion Welding and Cutting, S. W. Miller. Am. Welding Soc.—Jl., vol. 4, no. 9, Sept. 1925, pp. 29–45, 35 figs. It is concluded that effect of welding heat on low-carbon steel of good quality is small, but effect on high-carbon steel is great; therefore as low carbon steel should be used as possible; there is a point of maximum ductility and minimum strength at distance from weld, depending on process used, and this is point at which rupture occurs with clean steel.

Oxyacetylene. See OXYACETYLENE WELDING.

Rails. See RAILWAY TRACK, WELDING.

Rods. Control of Manufacture and Acceptance Tests of Welding Rods, H. M. Carter. Am. Welding Soc.—Jl., vol. 4, no. 10, Oct. 1925, pp. 29–31. Outline of methods necessary in controlling good-quality welding rod.

High Strength Welds, J. R. Dawson. Am. Welding Soc.—Jl., vol. 4, no. 10, Oct. 1925, pp. 23–28. Brief account of outstanding features of High Test welding rod, which is a steel of unusual composition and may be suitably applied in most instances of steel welding.

Steel Tubing for Aircraft. Welding of Carbon and Alloy Steel Tubing for Aircraft, J. B. Johnson. Acetylene Jl., vol. 27, no. 6, Dec. 1925, pp. 278–280 and 284–286, 11 figs. Examples of application; welding operations and processes; study of failures; process which had most general application is welding by oxyacetylene flame; electric welding has been used but is still on experimental basis.

Thermit. See THERMIT WELDING.

Wire. Welding Wire a Factor in Good Welding, C. A. McCune. Am. Welding Soc.—Jl., vol. 4, no. 10, Oct. 1925, pp. 32–36. Suggests test methods as further means of determining qualities of wire.

WINDMILLS

Small Plants. Small Wind-Power Plants (Kleinwindkraftanlagen), Lubowsky. Elektrotechnik u. Maschinenbau, vol. 43, no. 47, Nov. 22, 1925, pp. 921–927, 5 figs. Discusses importance of regular survey of wind power available in given localities; AEG instruments used; viewpoints of meteorologist, mechanical and electrical engineers, and consumer to be met in wind-power-plant construction: development of unit plants in Germany on American model.

WORKMEN'S COMPENSATION

Industrial Accidents. Work of the International Association of Industrial Accident Boards and Commissions, O. F. McShane. Monthly Labor Rev., vol. 21, no. 4, Oct. 1925, pp. 1–5. Formation and purposes of and work accomplished by Association; reduction of accidents; standardization of medical service; industrial rehabilitation; standardization of computing costs and of administrative practice; improvement of legislation; standardization of statistics.

Social Insurance and. Workmen's Compensation and Social Insurance. Monthly Labor Rev., vol. 21, no. 3, Sept. 1925, pp. 136–146. Referendum on Missouri Workmen's Compensation Law, Lindley D. Clark; recent compensation reports; cost of compensation for industrial accidents; trade-union benefits for boot and shoe workers.

WROUGHT IRON

Manufacture and Uses. The Manufacture and Use of Wrought Iron, H. E. Smith. Am. Iron & Steel Inst.—advance paper, for mtg. Oct. 23, 1925, 6 pp. For judgment of physical properties, tensile, and bending tests are very satisfactory; with respect to chemical composition in general, carbon should be present in only minute amounts; physical tests and etching for specification purposes; practical uses of wrought iron.

Mechanical Puddling. The Ely Process of Mechanical Puddling for the Production of Wrought Iron, F. H. Dechant. Am. Iron & Steel Inst.—advance paper, for mtg. Oct. 23, 1925, 11 pp., 3 figs. Describes Ely furnace, first designed and built for purpose of busheling scrap iron mechanically; its adaptation for puddling of pig iron was started about 4 years ago and modifications, which have been prompted by experience through this period, have resulted in practical mechanical puddling machine; in author's opinion, this furnace occupies position in field of mechanical puddling of being adaptable and flexible in its application to wrought-iron works and therefore of practical and economic worth.